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DEPARTMENT OF THE INTERIOR
BUREAU OF MINES
JOSEPH A. HOLMES, DIRECTOR

WASTE OF OIL AND GAS

IN THE

MID-CONTINENT FIELDS

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ENGINEERING

BY

RAYMOND S. BLATCHLEY

ENGIN STORAGE

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WASTE OF OIL AND GAS IN THE MID-CONTINENT FIELDS.

By Raymond S. Blatchley.

INTRODUCTION.

During the month of December, 1912, the writer was assigned to investigate the past and existing waste of gas and oil in the Mid-Continent fields, which include the fields of Kansas, Oklahoma, and northern Texas. This report, which is the result of that investigation, describes the general amounts and kinds of waste, and attempts to show the importance of conserving these natural resources. It does not present general rules and regulations for reducing the waste of gas and oil, except in two extreme cases, but suggestions are made that are intended to help the operator meet the situation. The right kind of cooperation should accomplish more than the enactment of drastic regulations.

The time allowed for this investigation permitted only the most general study. Details of individual fields were obtained only in such places as are representative of those areas. This report is largely a general compilation of the data from each of the areas.

The report deals with the waste of gas in Kansas, the waste of oil and gas in Oklahoma, including a summary of the past and present waste, the kinds of waste, and conclusions containing a number of suggestions for the conservation of oil and gas. The waste of oil is discussed very briefly and the discussion is confined to the waste in several areas in northeastern Oklahoma. In regard to the output of wells, as given in this paper, it must be remembered that the methods in use for measuring oil and, especially, gas give approximate results, and in many cases the output is estimated.

ACKNOWLEDGMENTS.

Acknowledgments are due particularly to Prof. Erasmus Haworth, State geologist of Kansas, for the privilege of taking data from his report to the Public Utilities Commission of Kansas City, Mo., on the present supply of gas in Kansas and Oklahoma. Thanks are due to D. W. Ohern, State geologist of Oklahoma, for his kindly interest in the problem and for his assistance in certain localities that were

visited. Thanks are also due to numerous oil and gas operators who kindly furnished information of the productive areas, particularly in Oklahoma. I. C. Allen and G. A. Burrell, of the Bureau of Mines, analyzed selected oil wastes and gas samples.

WASTE OF GAS IN KANSAS.

INTRODUCTION.

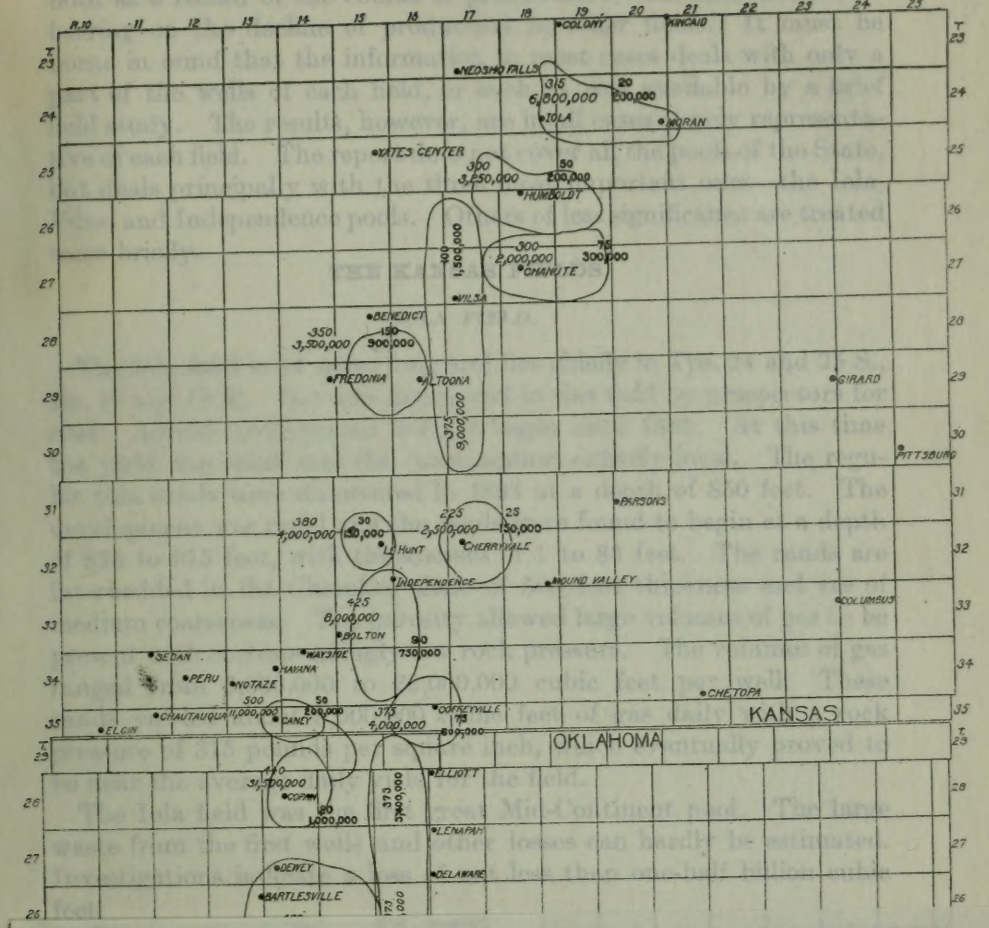
The early development of oil and gas fields in Kansas began with the search for gas near Paola. The results were satisfactory and soon the value of gas as a fuel was recognized. The main development of the gas industry began in the eighties and continued until within the last two or three years.

There was no notable waste until high rock pressures and large volumes of gas were obtained in the southeastern part of the State. On the whole, with two or three exceptions, the gas has been reasonably well conserved by extensive domestic and industrial use. One example of willful waste was in connection with the famous Caney gas well near the boundary line of Oklahoma and Kansas. This well is presumed to have produced 50,000,000 cubic feet of gas daily. It was allowed to burn openly for a long time, and was eventually capped by J. C. McDowell. The process is described by H. W. Talbott.[a]

The principal present evident waste of gas in Kansas is due to the escape of "casing-head gas" from oil wells. It is estimated that the average producing oil well will yield about 300,000 cubic feet of casing-head gas a day. The actual amounts vary from nothing to 1,000,000 cubic feet. Operators claim that shutting in the casing-head gas interferes with the yield of oil. Consequently many wells are not capped, only enough gas is utilized to provide individual leases with fuel or light, and surplus gas is wasted in order to maintain the low pressure in the casing. However, the wells should be capped, the pressure increased by pumps, and the gas turned into the gas lines.

The most important indirect phase of waste is the rapid decline of fields of originally high pressures and large flows, through exploitation of the fields by the operating companies. This phase of the question is emphasized in the discussion of the leading gas areas of Kansas and by the comparative figures presented in Plate I. The larger part of the data compiled in this chapter, with the accompanying illustrations, is taken from Haworth's report on the present gas supply, made to the Public Utilities Commission of Kansas City, Mo. The data collected by Haworth cover the period from the early developments to November 1, 1911, and is of the greatest value

[a] Talbott, H. W., The burning gas well at Caney, Kansas: Eng. and Min. Jour., vol. 81, May 19, 1906, p. 945.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COLONY
KINCAID
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315
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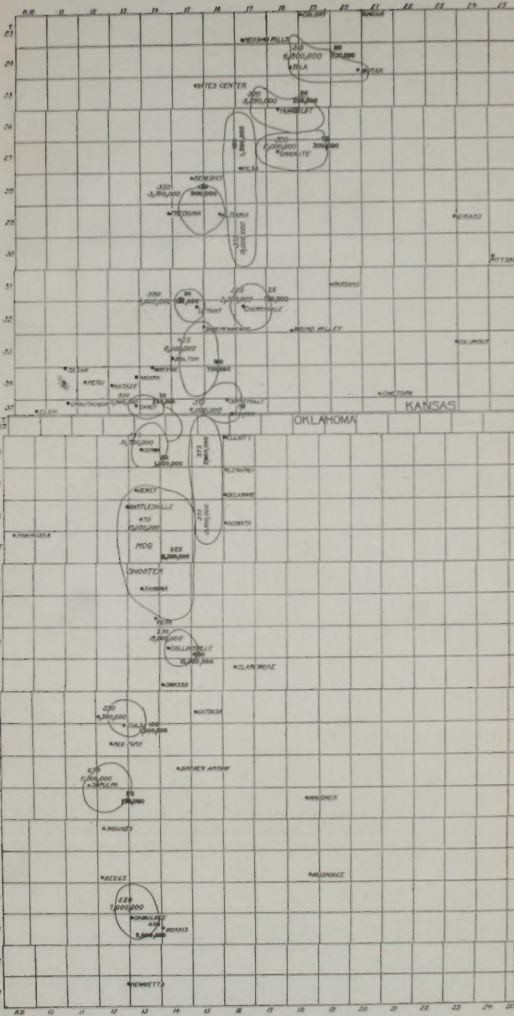
20
200,000
IOLA
MORAN
YATES CENTER
300
3,250,000
50
200,000
HUMBOLDT
100
1,500,000
300
2,000,000
75
300,000
CHANUTE
WILSA
BENEDICT
350
3,500,000
150
300,000
FREDONIA
ALTOONA
375
9,000,000
GIRARD
PITTSBURG
PARSONS
380
4,000,000
30
150,000
225
2,500,000
25
150,000
LE HUNT
CHERRYVALE
INDEPENDENCE
MOUND VALLEY
COLUMBUS
425
8,000,000
BOLTON
90
730,000
SEDAN
MAYSVILLE
HAVANA
PERU
NOTAZE
CHETOPA
50
200,000
500
11,000,000
CHAUTAUQUA
CANEY
375
4,000,000
75
800,000
CORFEYVILLE
ELGIN
KANSAS
OKLAHOMA
110
31,500,000
COPAN
ELLIOTT
373
3,000,000
90
1,000,000
LENAPAH
DEWEY
DELAWARE
BARTLESVILLE



MAP OF MID-CONTINENT GAS FIELDS, SHOWING POOLS.

Italic figures show original rock pressures and daily yields; heavy figures show pressures and yields in November, 1911.

both as a record of the course of production in the field and for its bearing on the decline of production in other fields. It must be borne in mind that the information in most cases deals with only a part of the wells of each field, or such as was available by a brief field study. The results, however, are in all cases closely representative of each field. The report does not cover all the pools of the State, but deals principally with the three most important ones—the Iola, Vilas, and Independence pools. Others of less significance are treated more briefly.

THE KANSAS FIELDS.

IOLA FIELD.

The Iola field is 14 miles long and lies chiefly in Tps. 24 and 25 S., Rs. 18 and 19 E. Gas was discovered in this field by prospectors for coal. Actual development did not begin until 1885. At this time the yield was small and the consumption entirely local. The regular Iola sands were discovered in 1893 at a depth of 850 feet. The development was rapid and the sands were found to begin at a depth of 835 to 975 feet, with thicknesses of 1 to 85 feet. The sands are interbedded in the Cherokee shale of 500 feet thickness and are of medium coarseness. The porosity allowed large volumes of gas to be present with correspondingly low rock pressure. The volumes of gas ranged from 5,000,000 to 22,000,000 cubic feet per well. These sands yielded about 8,000,000 cubic feet of gas daily with a rock pressure of 315 pounds per square inch, which eventually proved to be near the average daily yield for the field.

The Iola field was the first great Mid-Continent pool. The large waste from the first wells and other losses can hardly be estimated. Investigations indicate a loss of not less than one-half billion cubic feet.

Many manufacturing interests centered at Iola after the field had been placed under control and gas was ready for the market. Gas was used in zinc smelting, in the manufacture of sulphuric acid, in cement and brick plants, as a fuel for gas engines and boilers, and for domestic use. In fact, the gas from this field has never been piped out for use elsewhere. Up to November 1, 1911, 1,129 producing wells had been drilled, with 893 abandoned and 236 active at that date. The following figures, by Haworth, of a few of the wells present the proportionate rate of decline:

Decline in rock pressure of some of the Iola wells.

	Original.	September, 1911.
Number of wells	7	21
Average rock pressure per well ..... pounds per square inch..	309	42.5
Average rock pressure of 14 selected wells ..... do....	.....	60.8

Decline in volume of some of the wells in the Iola field.

	Original.	September, 1911.
Number of wells	7	19
Total volume.....cubic feet	48,500,000	7,770,000
Average volume per well.....do	6,928,000	409,000
Average volume of 14 wells.....do	.....	535,000

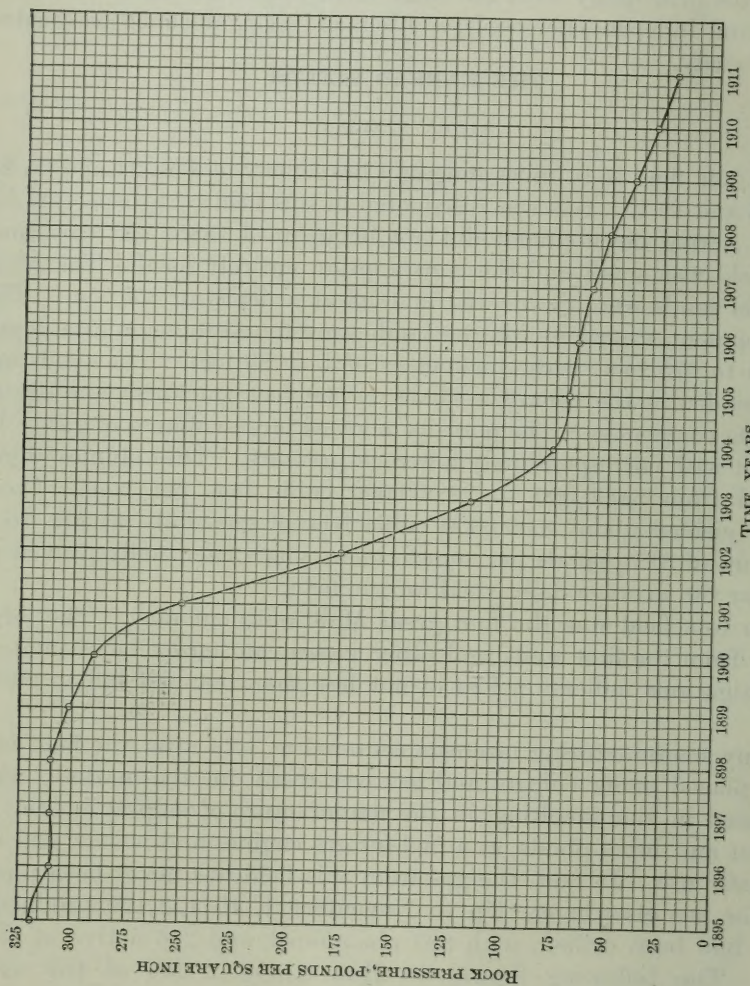


FIGURE 1.—Curve showing decrease of rock pressure in the Iola field.

The importance of this field as a producer is past, as indicated by the above table, Plate I, and figure 1. The daily consumption from 1901 to 1906 was at least 75,000,000 cubic feet, which was greatly in excess of the most economical yield and impaired the life of the area. As a result the decline was very rapid. The demands of extensive manufacturing interests for fuel quickly drained this field; whereas if the daily yield had been reduced to 30 to 40 per cent of the capacity

of the wells, the demand being decreased in proportion, the life of the field would undoubtedly have been extended 10 to 15 years. The quick drain of the area increased the possibility of drowning the field by salt water, which fills the lower strata and retards the movement of the oil and gas through the sands. Both the excessive consumption of gas and the drowning of the remnants of the field are due to the greedy exploitation of the field by the operators concerned, and therefore come under the head of loss or waste. The problem of preventing waste in this manner is one of grave importance.

HUMBOLDT FIELD.

The Humboldt field lies round about Humboldt. The main producing part extends 8 to 10 miles east and southeast of Humboldt. One well with a daily capacity of 15,000,000 cubic feet was drilled near Chanute. Since 1903, many good wells have been drilled, with excellent pressures and volumes of gas. The supply has so diminished that the field is at present abandoned.

The first well in 1903 is said to have produced 9,500,000 cubic feet of gas daily with a rock pressure of 300 pounds. A new well, on the same farm, in 1905 produced 2,500,000 cubic feet of gas at a rock pressure of 127 pounds. In 1910 a new well was drilled to 52 feet of coarse sand and found no gas.

The initial pressure of the wells of one company was 350 pounds, while to-day the pressures of the same wells are 40 to 80 pounds and the yields are 100,000 to 400,000 cubic feet (through a 2-inch pipe) in 24 hours. This company has adopted the plan of connecting all its wells and thus equalizing the pressures. This adds to the life of the weaker wells. One-half to one-inch pipes are placed in the wells, extending to the bottom, which serve by gas pressure to jet salt water from the wells.

Hundreds of wells have been drilled in this field with volumes from 1,000,000 to 10,000,000 cubic feet, but the larger wells were used too quickly and within three years they were exhausted. At present the industrial concerns of near-by towns are using gas from the Oklahoma fields, as their own supply is inadequate. A large gas company operating in this field drew a much larger amount of gas from the field than did the local consumers.

The comparative figures of original and present volumes and rock pressures are given by Haworth as follows:

Decline in rock pressures of wells in the Humboldt field.

	Original.	September, 1911.
Number of wells	99	149
Average rock pressure per well.....pounds per square inch..	295	37
Average rock pressure for 79 wells.....do....	.....	71

Rock pressures of wells of a large company.

Number of wells	35
Average rock pressure per well ..... pounds per square inch..	44

Decline in volumes of wells of the same company.

	Original.	September, 1911.
Number of wells	95	149
Total volume ..... cubic feet..	286,900,000	20,020,000
Average volume per well ..... do....	3,020,000	134,400
Average volume for 79 wells ..... do....	.....	270,540

CHANUTE FIELD.

The early development of the Chanute field took place immediately east of the town of Chanute. The wells produced about 5,000,000 cubic feet of gas a day. A pool was opened about 9 miles northeast of Chanute, the first wells showing rock pressures of 300 pounds and volumes of 1,000,000 to 15,000,000 cubic feet a day. The average volume for 40 gas wells in the area was 3,000,000 cubic feet a day. About two-thirds of these wells are now active, with 40 pounds rock pressure, a volume of 50,000 to 300,000 cubic feet a day, and a working pressure of 25 to 27 pounds in the field.

Another pool was opened in 1910 about 6½ miles southwest of Chanute. Twenty wells were drilled with rock pressures of 260 pounds and volumes of only 500,000 to 3,000,000 cubic feet a day—an average of 800,000 cubic feet a day. These wells were connected to city lines October 20, 1910. By January 15, 1911, the pressure had decreased to 45 pounds. The volumes of the wells are variable and dependent on the thickness, coarseness, and porosity of the sand. In most of the pools, and especially in the Vilas pool, the sands lie deeper toward the west and the rock pressures accordingly become greater. The town of Chanute consumes about 5,000,000 cubic feet of gas daily during the cold months, and in January, 1913, there seemed to be enough gas for local consumption.

The following figures compiled by Haworth show the decline of the field:

Decline in rock pressures of wells in the Chanute field.

	Original.	September, 1911.
Number of wells	147	194
Average rock pressure per well ..... pounds per square inch..	262	53
Average rock pressure for 97 selected wells ..... do....	.....	106

Decline in volume of wells in the Chanute field.

	Original.	September, 1911.
Number of wells	131	188
Total volume.....cubic feet..	251,300,000	32,217,000
Average volume per well.....do....	1,918,320	171,300
Average volume for 98 selected wells.....do....	.....	328,750

VILAS FIELD.

The Vilas field lies in Tps. 26 to 30 S., Rs. 16 and 17 E., thus forming a long slender area 28 miles long and about 5 miles wide. The field rests upon a narrow anticlinal ridge. It merges into the Chanute and Fredonia-Altoona fields. The Vilas field has been one of the most productive pools of the Mid-Continent field, but is depleted to a great extent now. The first large gas well of Kansas, known as the Caubel well, was situated about 2½ miles east of Benedict, in this area. This well is reported to have produced over 3,000,000,000 cubic feet of gas, which was piped 16 miles to Chanute and made a handsome profit for its owners, although sold at a very low rate. The well was permitted to flow openly for three weeks in the hope of obtaining oil. After it was capped it served Chanute for two years.

An important gas company of Kansas drew heavily from this field. The waste has been very large, and in addition the wells of the company are now drawn almost to exhaustion (see comparative figures below), which has greatly affected the entire pool. There is sufficient gas left for local domestic use.

The comparative pressures and volumes, according to Haworth, are as follows:

Decline in rock pressures of wells in the Vilas field.

	Original.	September, 1911.
Number of wells	78	77
Average rock pressure per well.....pounds..	330	154
Average rock pressure for 56 selected wells.....do....	.....	212

Rock pressures of the wells of a large company.

Number of wells	66
Average rock pressure per well.....pounds..	28
Average rock pressure for 64 wells.....do....	29

Decline in volume of wells of same company.

	Original.	September, 1911.
Number of wells	44	78
Total volume.....cubic feet..	393,030,000	121,825,000
Average volume per well.....do....	8,932,500	1,562,000
Average for 55 selected wells.....do....	.....	2,215,000

FREDONIA-ALTOONA FIELD.

The Fredonia-Altoona field lies between the towns of Fredonia and Altoona, in Tps. 28 to 30 S., Rs. 15 to 17 E. This field contained some large wells with rock pressures as high as 400 pounds and volumes ranging from 10,000,000 to 22,000,000 cubic feet a day. There are many large wells in this field of which data were not available. Although the drain has been heavy, the field is still a good producer.

Decline in rock pressures of wells in the Fredonia-Altoona field.

	Original.	September, 1911.
Number of wells	128	177
Average rock pressure per well.....pounds..	301	52
Average for 12 selected wells.....do....	.....	76

Decline in volume of wells in the Fredonia-Altoona field.

	Original.	September, 1911.
Number of wells	81	97
Total volume.....cubic feet..	248,750,000	29,540,000
Average volume per well.....do....	3,070,900	304,500
Average volume for 40 selected wells.....do....	.....	775,000

CHERRYVALE FIELD.

The Cherryvale field lies east, southeast, and northeast of Cherryvale. Gas was discovered in 1889 and soon became an important industrial factor. One large zinc plant, at least seven brick plants, and a glass factory were established at Cherryvale and drew their fuel supply from the local fields. The growth of the town is emphasized by the difference in population—1,800 in 1890 and 5,572 in 1911. This field is now exhausted. The average daily consumption of Cherryvale and its business interests was 12,150,000 cubic feet. The wells of this field produced large volumes, but the rock pressures were small owing to the shallow depth of the wells. Several wells 600 feet in depth produced daily volumes of 5,000,000 cubic feet or more.

The following figures indicate the decline of the Cherryvale field:

Decline in volume and rock pressure of wells in the Cherryvale field.

Date.	Average rock pressure per well.	Average volume per well.	Total volume.
	Pounds.	*Cubic feet.*	*Cubic feet.*
1889 [a]	221	2,560,000	107,532,000
June 1, 1906	111	1,771,576	.....
June 1, 1907	94	962,040	.....
June 1, 1908	47	265,392	.....
June 1, 1909	20	91,432	.....
June 1, 1910	11	85,600	.....
June 1, 1911	8	28,810	.....

[a] Number of wells, 42.

The decline of this field is further shown by the curves of figure 2.

LE HUNT FIELD.

The Le Hunt field is situated in Tps. 31 and 32 S., R. 15 E. It merges on the south with the Independence field. The Le Hunt field originally possessed rock pressures up to 400 pounds, but the volumes of the wells were only 1,000,000 to 5,000,000 cubic feet a day. The wells were deep, hence the high pressures. There is a large cement plant situated at Le Hunt which has greatly exhausted this field and

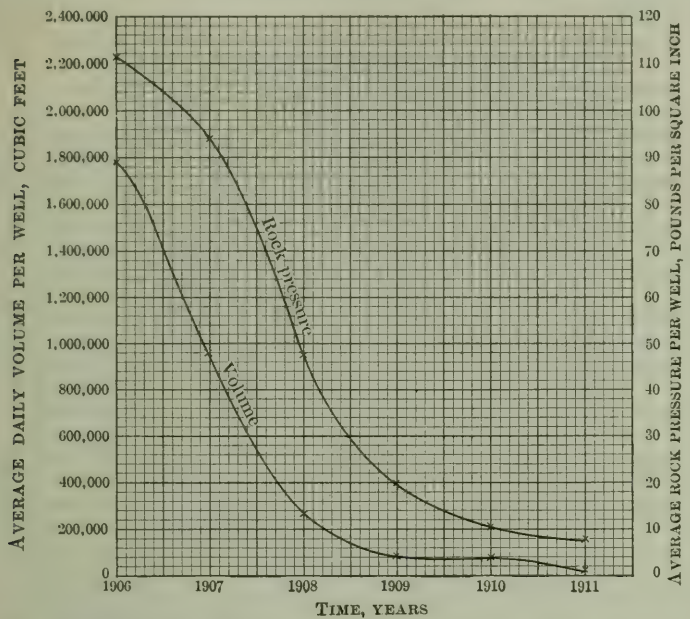


FIGURE 2.—Curves showing the decline in volume and rock pressure of wells in the Cherryvale field.

at present is using natural gas piped from Oklahoma. The following figures show the decline in pressures and volumes:

Decline in volume and rock pressure of wells in the Le Hunt field.

Date.	Average rock pressure per well.	Average volume per well.	Total volume.
	Pounds.	*Cubic feet.*	*Cubic feet.*
Original [a]	382	4,714,000	89,567,000
June 1, 1906	263	1,529,364	.....
June 1, 1907	200	909,504	.....
June 1, 1908	165	811,492	.....
June 1, 1909	139	356,960	.....
June 1, 1910	143	364,960	.....
June 1, 1911	None.	None.	.....

[a] Date unknown; number of wells, 19.

INDEPENDENCE FIELD.

The Independence pool lies north, southeast, and northwest of Independence in Tps. 32 to 34 S., Rs. 15 and 16 E. The first wells of the field were drilled immediately east of Independence. The rock pressures and volumes were light, and hence the life of the area was brief. The wells to the northwest are of greater depth and had high initial rock pressures, as much as 500 pounds in some cases. The largest wells were 3 to 6 miles south of Independence. The initial yield

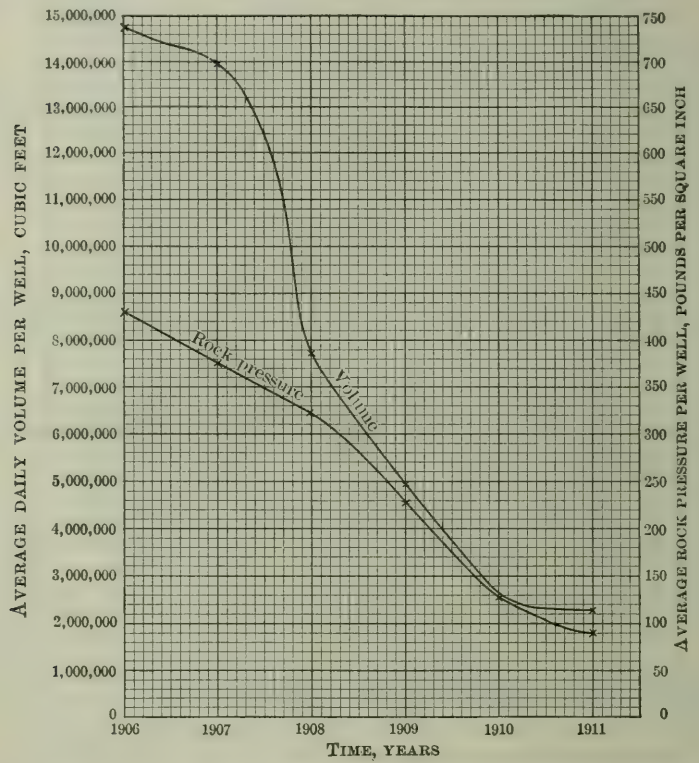


FIGURE 3. -Curves showing the decline in volume and rock pressure of wells in the Independence field.

of one well, now exhausted, was 40,000,000 cubic feet a day. In this area a daily flow of 10,000,000 cubic feet was accounted small. The average volume per well was probably more than twice as large.

One of the large gas companies drew heavily from this field from 1907. Pipe lines have furnished Joplin, Mo., with gas from this field since 1905. One large cement plant, a vitrified brick plant, several other brick plants, and several glass plants consumed 16,000,000 cubic feet daily for a long time from the area. The company mentioned above obtained 10 per cent of its supply from this field at the time it was visited. Because of the coarseness of the producing sand the drain has been rapid. The following figures show the decline of this field, which is graphically indicated by the curves in figure 3.

Decline in volume and rock pressure of wells in the Independence field.

Date.	Average rock pressure per well.	Average volume per well.	Total volume.
	Pounds.	*Cubic feet.*	*Cubic feet.*
Original [a]	390	7,817,000	1,664,957,000
June 1, 1906	429	14,729,848	.....
June 1, 1907	375	13,945,040	.....
June 1, 1908	323	7,763,956	.....
June 1, 1909	229	4,924,752	.....
June 1, 1910	129	2,541,820	.....
June 1, 1911	91	2,289,104	.....

[a] Date not known; number of wells, 213.

COFFEYVILLE FIELD.

The Coffeyville field surrounds the town of Coffeyville and extends westward 8 miles to Tyro. The first area of development was under and about Coffeyville, but this area did not produce large quantities of gas. The chief gas area lies a few miles to the west. Many of the older wells of this field produced about 15,000,000 cubic feet of gas at a rock pressure of 400 pounds. Little information is available except on later wells. The field has been nearly exhausted in supplying gas for manufacturing use. Several of the factories in this area now use oil as fuel instead of gas. The early waste of gas from this field was very large.

Information regarding 15 later wells gives the following results:

Original volumes and rock pressures of 15 of the later wells.

Average rock pressure per well	pounds per square inch	361
Total volume	cubic feet	58,524,000
Average volume per well	do	3,903,600

The following figures show the rate of decline of the Coffeyville field:

Decline in volume and rock pressure of wells in the Coffeyville field.

Date.	Average rock pressure per well.	Average volume per well.
	Pounds.	*Cubic feet.*
June 1, 1906	346	3,900,272
June 1, 1907	275	3,803,640
June 1, 1908	299	3,595,588
June 1, 1909	243	3,478,680
June 1, 1910	162	2,716,608
June 1, 1911	101	1,105,008

CANEY FIELD.

The Caney field lies east and southeast of Caney. It connects southward with the Copan field of Oklahoma. The wells of the Caney field are 1,500 to 1,700 feet deep. The rock pressures were correspondingly high, as much as 700 pounds per square inch in some

wells, and the volumes were large. The field, however, is limited in extent and was rapidly depleted. The daily consumption of gas at one time in Caney reached as high as 7,950,000 cubic feet.

Information on the field was scant, but enough was obtained to present an idea of the original pressures and volumes:

Original volume and rock pressure of wells in the Caney field.

Number of wells		13
Average rock pressure per well	pounds per square inch	490
Total volume	cubic feet	139,028,000
Average volume per well	do	10,694,400

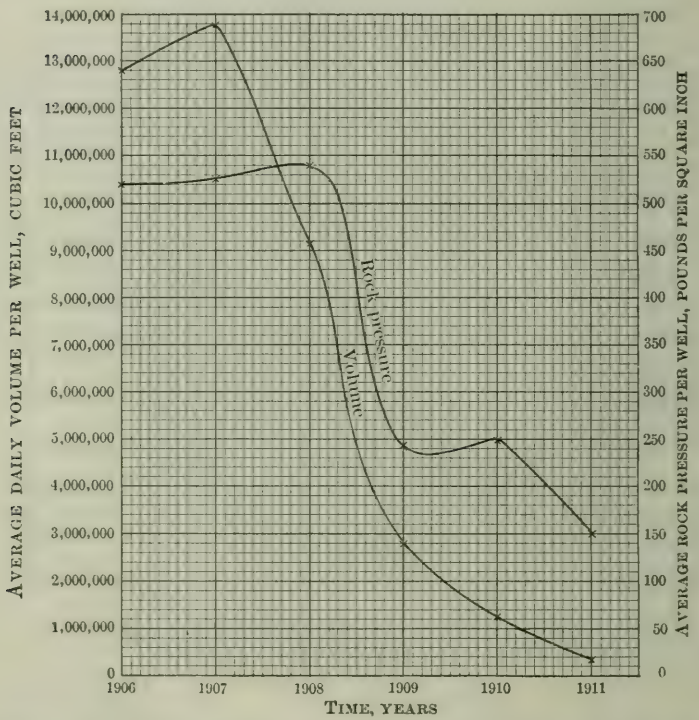


FIGURE 4.—Curves showing the decline in volume and rock pressure of wells in the Caney field.

The decline of the Caney field is shown in the curves[a] of figure 4 and by the following figures:

Decline in volume and rock pressure of wells in the Caney field.

Date.	Average rock pressure per well.	Average volume per well.
	Pounds.	*Cubic feet.*
June 1, 1906	523	12,789,124
June 1, 1907	528	13,797,027
June 1, 1908	540	9,140,000
June 1, 1909	243	2,865,000
June 1, 1910	250	1,243,200
June 1, 1911	150	314,000

[a] The ascent of the curves is caused by new wells being added to the field in intermediate years.

MONTGOMERY COUNTY FIELD.

The Montgomery County field includes the Caney, Cherryvale, Deering, Independence, Le Hunt, Sycamore, and Tyro pools.

The following figures compiled by Haworth show the decline of the Montgomery County field as a whole:

Decline in rock pressure and volume of wells in the Montgomery County field.

	Original.	September, 1911.
Number of wells	681	389
Average rock pressure per well.....pounds per square inch	259	98.8
Total volume.....cubic feet	2,531,458,000	462,222,000
Average volume per well.....do	3,717,000	1,188,000

The following figures show the decline of the various pools of the Montgomery County field:

Decline in yield and rock pressure of pools in the Montgomery County field.

Pool.	Year.					
	1896		1906		1911	
	Rock pressure.	Volume.	Rock pressure.	Volume.	Rock pressure.	Volume.
	Pounds.	*Cubic feet.*	*Pounds.*	*Cubic feet.*	*Pounds.*	*Cubic feet.*
Caney	600	22,400,000	523	12,789,124	150	314,000
Cherryvale	180	3,780,000	111	1,771,576	8	28,810
Coffeyville	450	6,250,000	346	3,900,272	101	1,105,008
Deering	465	9,700,000	382	4,953,024	108	895,920
Independence	482	21,600,000	429	14,729,848	91	2,289,104
Le Hunt	310	3,900,000	263	1,529,364	143	100,000
Sycamore	405	2,280,000	306	733,040	234	180,000
Tyro	580	4,300,000	164	2,091,333	292	583,036
Average for Montgomery County	434	9,276,250	353	5,312,198	181	686,984

Some pools that have produced small quantities of gas are not included in the above table. These are two small pools east and west of Paola, and the Osawatomie, Garnett, Erie, New Albany, and Liberty pools.

DISTRIBUTION OF GAS.

The location of the pipe lines and the areas of distribution are shown on Plate II. These lines furnish gas to about 450,000 people in Kansas and 445,000 people in Missouri. About 250,000 consumers reside in and about Kansas City.

The Mid-Continent fields supply gas to over 1,100,000 people. About 45 per cent of the general supply is consumed by factories, while the remaining 55 per cent is used for domestic purposes. In many of the areas, however, as high as 75 per cent is used locally for industrial purposes.

A large company first delivered natural gas to Kansas City November 19, 1906. The northern Kansas cities, however, received gas in the autumn of 1905 from the territory north of Montgomery County—Allen, Wilson, and Neosho Counties. In 1907 the lines to these towns were extended into Montgomery County. The Oklahoma extensions followed in the fall of 1909. On November 1, 1911, the proportionate rate of supply was Oklahoma, 65 per cent; Montgomery County, Kans., 25 per cent; and Wilson, Allen, and Neosho Counties, Kans., 10 per cent. The present rate of supply is about 75 per cent for Oklahoma and 25 per cent for Kansas.

A single company during 1910 and 1911 sold gas from these fields as follows:

Sales of a Kansas company during 1910 and first half of 1911.

	1910	First half of 1911.
	Cubic feet.	*Cubic feet.*
Oklahoma	8,914,000,000	8,208,000,000
Montgomery County, Kans.	18,573,319,000	6,050,613,000
Wilson County, Kans.	4,375,180,000	1,699,897,000
Allen and Neosho Counties, Kans.	1,814,920,000	846,288,000
Total	33,677,419,000	16,804,798,000

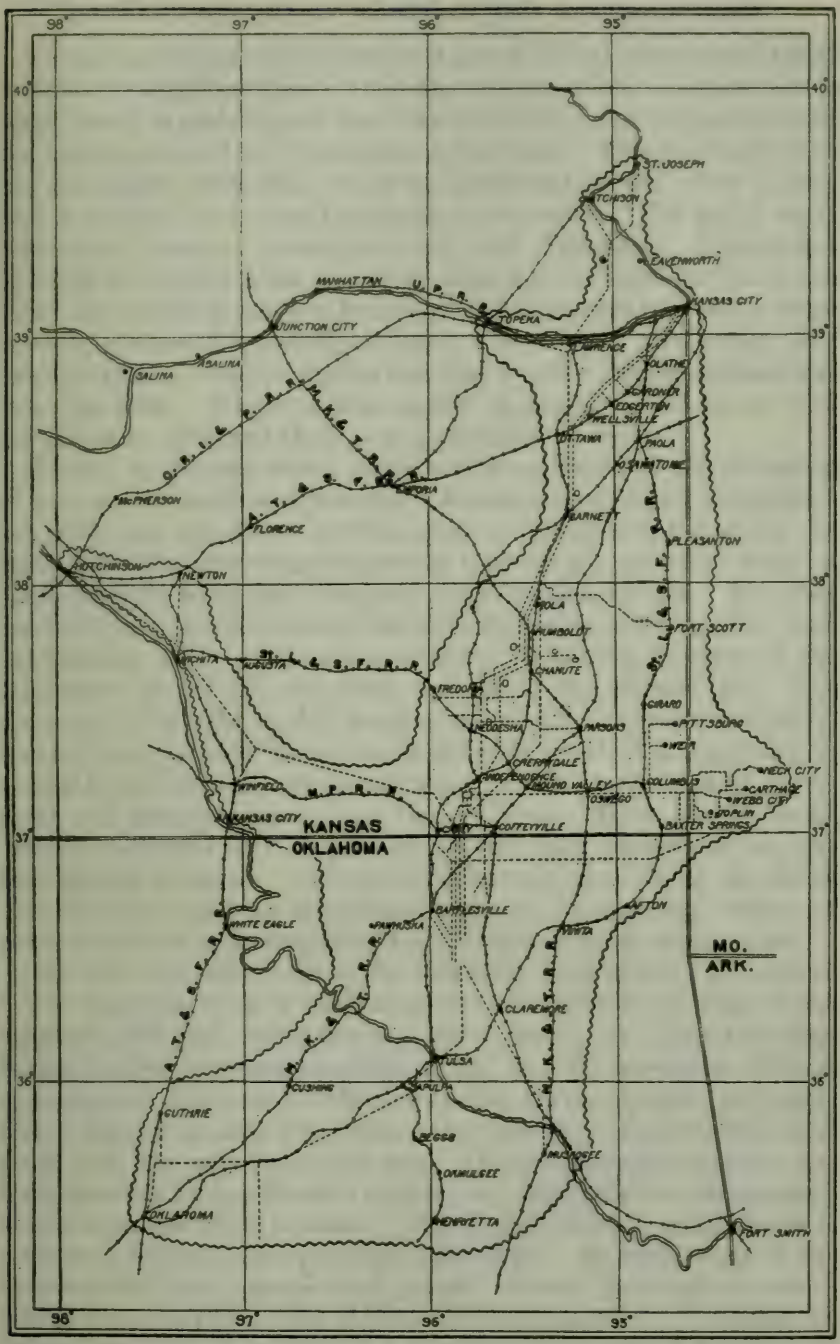
This company procured an additional 15,000,000 cubic feet a day from Oklahoma on December 9, 1912, and a like amount December 15, 1912. The total daily supply of these lines is about 60,000,000 cubic feet, which is delivered to over 20 cities. The daily demand on this company in cold weather is 70,000,000 cubic feet.

The average daily consumption of the towns of Kansas using large quantities of oil and gas is as follows:

Average daily consumption of gas by Kansas towns.

Towns.	Population.		Consumption.
	1890	1911	
			Cubic feet.
Caney	668	5,061	7,954,000
Cherryvale	1,800	5,572	12,150,000
Coffeyville	2,492	15,350	8,804,000
Deering	.....	219	4,370,000
Independence	2,200	10,651	16,502,400
Le Hunt	.....	560	7,070,000
Sycamore	.....	200	750,000
Tyro	.....	.....	1,240,000

In order to meet the insistent demands for gas the producing territory must be drained in excess of its normal capacity, to the detriment of total possible yield. The lives of the fields will be greatly shortened by the drowning of the remaining gas through encroaching salt water.



MAP SHOWING PIPE LINES OF MID-CONTINENT GAS FIELDS AND AREA OF DISTRIBUTION IN 1912. PIPE LINES ARE REPRESENTED BY BROKEN LINES.

PRESENT STATUS OF WASTE IN THE KANSAS FIELDS.

The most evident careless waste of gas in Kansas at present (1913) is that of casing-head gas. It is almost impossible to estimate this waste, but it is probably not less than 3,000,000 cubic feet a day from the large number of active oil wells in the State. This gas comes with the oil directly from the seat of its accumulation and often is very rich in gasoline and other liquefiable constituents. The gas of some territories, however, is variable in its yield of gasoline. Natural gas from all producing fields should be analyzed to determine the possibility of extracting gasoline from it. If the possible recovery is large enough, the gasoline should be saved. In many of the present day gasoline plants, vacuum pumps are used to draw the casing-head gas from the wells. Wherever this method is employed the connections are all made tight and there is no possibility of waste.

Kansas, by its past waste, offers a striking lesson in the damaging of gas areas by inefficient practice. Kansas has produced exceptional gas wells and contained several areas of immense total yield. In most cases the operating companies resorted to excessive drain of these fields to satisfy an ever-increasing demand for gas. Not only have the fields been depleted, but the exhaustion of the gas has been detrimental to the surrounding territory by causing invasion of the salt water which fills the beds underlying the oil and gas. The drowning of a field in this manner means abandonment, for movement of the gas from the porous medium in which it is found is prevented by the presence of the salt water, which has little or no movement and usually extends into the synclines. There should be an enforced law that only 25 per cent of the daily capacity of any gas field should be taken. This would give prolonged life to the fields. The capacity could be determined, perhaps, by applying stationary pressure meters and computing the volumes once or twice a week.

The large number of industries that have been induced to come to towns near gas areas is another source of depletion to these fields. Smelters and such industries as cement, brick, and glass manufacturing require immense amounts of fuel, and the assurance of large consumption gives rise to ridiculous prices for the gas per 1,000 cubic feet. Indeed, in early years many factories were established in local areas with the promise of free gas. The prices paid for gas in the industries has been as low as 1½ cents per 1,000 cubic feet and scarcely ever more than 10 or 12 cents. The present average price (1913) is estimated to be 5 cents per 1,000 cubic feet. As natural gas is the cleanest and best natural fuel known to man, the highest use to which it can be put is that of household consumption. Therefore all natural gas should be sold at a minimum price of not less than 25 cents per 1,000 cubic feet, and, where practicable, its use should be confined to domestic purposes.

It is estimated that about 2,500 gas wells have been drilled in Kansas with daily yields ranging from 500,000 to about 50,000,000 (Caney well) cubic feet. The waste per well will probably average about 10,000,000 cubic feet. This does not include the waste of the first 5 days, unnecessarily allowed in each case for the capping of a gas well. At this rate the past waste of gas amounts to about 25,000,000,000 cubic feet. In addition to this, a great number of oil wells have produced immense amounts of gas with the oil. In such a well at least 75 per cent of the gas has been wasted. It is not unlikely that the waste from this source is in excess of the casing-head waste. The following table gives the value of the natural gas produced in Kansas during the years 1889 to 1911:[a]

Value of natural gas produced in Kansas, 1889–1911.

Year.	Value.	Volume.
		Cubic feet.
1889	$15,873	
1890	12,000	
1891	5,500	
1892	40,795	
1893	50,000	
1894	86,600	
1895	112,400	
1896	124,750	
1897	105,700	
1898	174,640	
1899	332,592	
1900	356,900	
1901	659,173	
1902	824,431	
1903	1,123,849	
1904	1,517,643	
1905	2,261,836	
1906	4,010,986	69,322,633,000
1907	6,198,583	76,707,165,000
1908	7,691,587	80,740,264,000
1909	8,293,846	75,074,416,000
1910	7,755,367	59,380,157,000
1911	4,854,534	38,799,406,000
Total	46,609,585	

WASTE OF OIL AND GAS IN OKLAHOMA.

INTRODUCTION.

The extensive oil and gas pools of Oklahoma comprise the latest of the Mid-Continent fields. These pools have for the most part been developed within the last eight years. They lie chiefly in the northeastern part of the State, near the towns of Lenapah, Nowata, Muskogee, Copan, Bartlesville, in the Hogshooter area, and near the towns of Collinsville, Tulsa, Sapulpa, Hamilton, Bald Hill, Morris, Schulter, Blackwell, Ponca, Osage, Cleveland, Cushing, Colgate, Wheeler, Loco, and Madill.

[a] Oliphant, F. H., Mineral Resources of the United States, 1904, U. S. Geol. Survey, 1905, p. 782; Hill, B., Mineral Resources of the United States, 1911, U. S. Geol. Survey, 1912, p. 283, 302.

The waste of oil is briefly discussed, as time did not permit of detailed investigation. The losses are limited almost entirely to the loss of the waste oil, which consists of sediment formed by the steaming of oil; the thick residue left after oil is "cut" or emulsified with gas and salt water; the thick sediments formed by pumping; and the thick emulsion of water and oil. A further waste of oil is caused by evaporation after the oil reaches the surface and is placed in tanks.

The waste of gas in the Oklahoma fields has been as great, if not greater, than that in any of the other fields in America. All of the fields except those in the extreme eastern part of the State have produced exceptional quantities of gas.

The greatest waste has been with the gas accompanying the oil or lying slightly above the oil and containing oil vapors. This may be termed "wet" gas. "Dry" gas, on the other hand, is that from sands that produce gas alone and is free from oil vapors, or, rather, gas from typical gas wells. Two causes of gas waste are: First, where there is no market for the gas nor any immediate prospect of one the gas is allowed to escape openly; second, where gas occurs with the oil it is used to bring the oil to the surface. In the latter case, the oil is turned into "flow tanks," and the gas is allowed to go to waste. As a rule the gas accompanying the oil is rich in gasoline and the lighter hydrocarbons, the value of the waste products being thus increased.

General investigations were made in each field, the time available not permitting detailed inquiries. The older areas were investigated by Haworth, and much of his data on them is presented. The later fields, such as Cleveland, Cushing, Bald Hill, and the Schulter pools, were visited by the writer and are discussed with respect to the waste that came under his observation.

OIL WASTE.

BARTLESVILLE POOL.

The first pool visited was the Bartlesville, in the vicinity of Dewey. The oil in this area produces a heavy residue, which is allowed to collect in the receiving tanks, then drawn off and collected in a waste pit. Those operators who are particular of the condition of their properties cause the collected residue to be burned periodically. In many cases, however, the residue is allowed to flow over the retaining pit and down the gullies to the nearest stream. It often is allowed to run out of the waste pit and over the ground adjoining the tanks, where it is absorbed by the soil. After the lighter products are gone it forms a dirty, sticky mass.

A sample of residue (Lab. No. 941) from the Dewey area was dipped from an open pit on sec. 21, T. 27 N., R. 13 E. The chemical composition is given in Table 1.

CLEVELAND FIELD.

The newer portion of the Cleveland field, especially the Lauderdale pool, is about 6 miles southwest of Cleveland. The oil from this pool also yields much residue, caused by the oil being churned and emulsified by gas and water. Under such conditions the product can not be marketed until the oil is practically free of sediment. In several cases the flow pipes are turned into large pits, where the oil and residue separate by standing. The loss by evaporation is large in such instances. After the oil separates the remaining residue is burned. In some cases where the gas is wasted close by, the oil waste is not burned for fear of conflagration, and therefore is allowed to stand permanently. Evaporation continues until the mass has the appearance of a vat of grease.

A sample of oil residue (Lab. No. 942) was dipped from the waste pit in the NE. ¼ sec. 1, T. 20 N., R. 7 E. The chemical composition is given in Table 1.

There was, perhaps, nearly 12,000 barrels of residue in the 25,000-barrel pit from which the above sample was taken. The lighter oils had been run off and the waste was standing until it could be disposed of with safety.

The original Cleveland pool extends from Cleveland southward for several miles. The Cleveland sand in this field lies at a depth of about 1,600 feet. A sample of the oil was taken from well No. 13 on reserved school land in the S. ½ NE. ¼ sec. 6, T. 21 N., R. 8 E. There are 14 wells on a lease of 240 acres. The production of No. 13 was 40 barrels a day, while the lease production aggregated 300 barrels a day. The chemical composition of the sample (Lab. No. 944) of oil taken from the flow of well No. 13 is given in Table 1.

The wells of this locality made considerable residue, which was allowed, in the case of this lease, to flow down a hillside from the tanks and into an open ditch. A sample of the residue was dipped from a small pit in the path of the stream. The chemical composition of the sample (Lab. No. 943) is given in Table 1.

A large open pit, containing thick residue, was observed on the southwest edge of Cleveland. The pit is about 125 feet in diameter and contained about 25,000 barrels of the residue. The pit was built when the Glenn pool was opened and developed in 1906-7. The immense flow of oil from the Glenn pool required the full capacity of the pipe lines then in use. As a result, the Cleveland oil had to be stored temporarily. No runs of oil could be made, and since many of the wells had to be pumped, the oil was stored in the best manner possible. For this reason the Cleveland pit was built and about 250,000 barrels of oil stored in it. Evaporation, however, quickly reduced the oil to a thick residue. A large portion of the mass was later shipped from Cleveland. The balance remained in the pit several years.

CUSHING FIELD.

A sample of the excellent oil produced in the new Cushing field was taken from the No. 2 well, on the NW. ¼ sec. 32, T. 18 N., R. 7 E. The Wheeler sand lies at a depth of 2,140 feet in this locality. Most of the wells of the territory produce abundant gas with the oil, which is allowed to carry the liquid to flow tanks. The chemical composition of the sample (Lab. No. 945) is given in Table 1.

The Cushing field does not make much residue, primarily because the field is free of water. When the water does come, through the exhaustion of oil and gas, it may be expected that the oil will be more emulsified and form residue.

TABLE 1.—*Results of examination of samples of oil or residue.*

[R. S. Blatchley, sampler; W. A. Jacobs, analyst.]

Laboratory No.	941	942	943	944	945
Specific gravity at 15° C.	.9460	.9275	1.0370	.8435	.8365
Degrees Baumé at 60° F.	17.99	20.94	.....	35.97	37.36
Constituents:					
Gasoline.....per cent..	2.0	.....	3.4	1.8	0.2
Lamp oils.....do....	8.5	5.1	5.6	30.6	39.1
Lubricants.....do....	36.4	40.6	6.5	42.6	39.3
Paraffines and asphaltum.....do....	31.7	20.7	5.1	22.7	20.5
Organic matter insoluble in gasoline .....per cent..	3.8	0.3	1.2	.....	.....
Sand.....do....	1.3	1.0	9.7	.....	.....
Distilling losses.....do....	0.7	0.5	0.6	0.8	0.9
Water.....do....	15.6	31.8	67.9	1.5	0.0
	100.00	100.00	100.00	100.00	100.00

Laboratory No. 941.—Frank Johnston lease, sec. 21, T. 27 N., R. 13 E., Washington county, Okla. Sampled December 6, 1912. Sediment and residue from bottom of receiving tanks. It is burned periodically, about once in two weeks, in an open pit.

Laboratory No. 942.—Lauderdale, N. E. ¼ sec. 1, T. 20 N., R. 7 E., Okla. Sampled December 16, 1912.

Remarks.—"Waste product of oil. This lease produces 50 per cent of B. S."

Laboratory No. 943.—School land, S. ½ NW. ¼ sec. 6, T. 21. N., R. 8 E., Okla. Sampled December 16, 1912. Residue from pit.

Laboratory No. 944.—School land, NE. ¼ sec. 6, T. 21 N., R. 8 E., Okla. Sampled December 16, 1912. Pure oil from same sand and wells as Laboratory No. 943.

Laboratory No. 945.—Wheeler No. 2 well, NE. cor. NW. ¼ sec. 32, T. 18 N., R. 7 E. Sampled December 16, 1912. Oil of high gravity, 42° B., in the field.

At the prevailing price of Kansas and Oklahoma crude oil, 70 cents a barrel, the value of the usable oils, the sand, water, etc., being deducted, would be as follows:

Laboratory No.	941	942	943	944	945
Usable oils.....per cent..	78.6	66.4	20.6	97.7	99.1
Value.....cents..	55.03	46.48	14.42	68.39	69.37

PRESENT CONDITIONS IN THE OIL FIELDS OF OKLAHOMA.

Time did not permit the taking of further samples of residue. Observations were made in most of the Oklahoma fields and the following pools were found to produce considerable residue: Osage, Nowata, Muskogee, Bald Hill, Henryetta, Schulter, Hamilton, Morris, and the Glenn pool. As one man confidently put it, "More

waste oil had run down the creeks from the famous Glenn pool than was ever produced in Illinois." Such a statement, though perhaps far-fetched, conveys some idea of the immense waste that has occurred in this wonderful oil pool. The streams in the Glenn pool flow considerable salt water that has a very foul odor. Several smaller branches contained much oil waste. In most cases the oil waste is composed of an emulsion with water, which may be due to the following factors:

The wells are often drilled too deep and tap the water zone.

The oil is "cut" by inflowing water under high pressures.

The wells are overpumped and the oil is roiled by churning.

Gas may "cut" the oil, but it seems that this does not happen unless water is present and the process of emulsion is with a mixture of gas and water.

In all cases the oil under such conditions is unfit for the market until after separation. As residue accumulates it is sometimes disposed of either by burning or allowing it to run down the streams. The amounts of residue produced in most fields is small in proportion to the quantity of oil, and the operator feels no inclination to save the residue as he does not have a ready or profitable use for it.

In several of the newer fields many lease tanks containing oil were observed without protection of sheds or covers over the top. A considerable loss occurs by evaporation from such exposure. Tanks should be provided with sheds and tight covers to prevent oil evaporation during storage. A considerable part of the lighter products evaporates, especially in summer, and is allowed to escape. It is possible to condense these vapors in gasoline recovery.

The disposal of residue by burning or otherwise is a useless loss. This product should be utilized. The utilization of oil waste and methods of accumulating, gathering, and transporting the product ought to receive careful attention.

GAS WASTE.

THE OKLAHOMA FIELDS.

CALIFORNIA FIELD.

The California field lies northwest of Lenapah in Tps. 27 and 28 N., R. 15 E. It was developed in 1911, and at present furnishes considerable gas. The producing sand is fine grained and the wells are therefore of variable capacity. The following figures show the original pressure and yield of the field:

Original yield and rock pressure of wells in the California field.

Number of wells		24
Total volume	cubic feet	82,230,000
Average volume per well	do	3,426,000
Average rock pressure per well	pounds per square inch	373

COPAN FIELD.

The Copan field lies northeast of Copan close to the Kansas-Oklahoma line, in Tps. 28 and 29 N., R. 13 E. The eastern and northeastern part of this field was originally one of the greatest gas-producing areas in the United States. The famous Caney gas well, previously spoken of, lies in this area. The wells of the locality were deep, the rock pressures high, and the volumes large. The original rock pressures of this field were reported as between 450 and 530 pounds. As the sand was very coarse, the drain was rapid. The field was so depleted that in August of 1911 the rock pressure had decreased to only 25 pounds. The original flow is said to have been 300,000,000 cubic feet daily, and in August of 1911 it was down to 100,000,000 cubic feet. There were about 125 productive wells drilled in the field, of which over half are abandoned at present. The rapid decline of the field was early augmented by the use of vacuum pumps. Water entered the oil strata and portions of the field are now (January, 1913) drowned.

But little information concerning the early wells could be obtained. The following figures show the decline of the Copan field:

Decline of rock pressure of wells in the Copan field.

	Original.	September, 1911.
Number of wells	7	7
Average rock pressure per well.....pounds per square inch..	440	18
Average rock pressure for 5 selected wells.....do....		25

Decline in volume of wells in the Copan field.

	Original.	September, 1911.
Number of wells	6	6
Total volume.....cubic feet..	189,422,000	5,500,000
Average volume per well.....do....	31,570,000	916,000

BARTLESVILLE FIELD.

The Bartlesville field lies in Tps. 25, 26, and 27 N., Rs. 12 and 13 E. This field includes the Dewey and Webber pools extending about 7 miles northeast and the Osage lands 3 or 4 miles west. These pools are among the earliest discovered in Oklahoma. They originally showed medium pressures of gas, of which there is little or no information. Great quantities of gas were tapped in the Osage lands adjoining the Bartlesville area to the west and northwest. The gas and oil were close together, but the operators would have disposed of the gas had there been a common carrier and a market. The waste of gas from this area was very large.

The present waste in the Bartlesville area is chiefly that of casing-head gas. The Dewey area was visited and a sample of "combination" gas or that produced with the oil was taken from well No. 3, sec. 21, T. 27 N., R. 13 E., which had been drilled and shot two days previous, and at the time of the visit was blowing free through a 2-inch tubing and had a rock pressure of 55 pounds per square inch. The gas and oil came from a sand at a depth of 1,322½ feet. The chemical composition and fuel value of this gas (Lab. No. 3146) are given in Table 2.

A second sample (Lab. No. 3145) of casing-head gas was taken from well No. 5 in sec. 4, T. 26 N., R. 13 E. There were 11 wells on this lease of 80 acres, all of which are producing casing-head gas under 15 to 20 pounds rock pressure. Only one well, No. 5, was shut in. It was connected with the power house, a large flambeau, and the pump-house. The remaining wells are open. All of these wells date from 1906. They produced initially 1,000 to 1,500 barrels of oil a day. The accompanying gas, which was escaping freely at all the wells, had a rock pressure of 50 to 80 pounds. The lease is one of a large number in the area that openly permits the waste of a rich gas. The chemical composition and fuel value of this gas are given in Table 2.

A small gas field lies east and southeast of Dewey. There are about 15 wells in this field, which yield a total volume of about 20,000,000 cubic feet a day. The rock pressure in November, 1911, varied from 130 to 475 pounds, with an average of 300 pounds. The initial rock pressures were as high as 500 pounds, but the present (January, 1913) pressures are less than 150 pounds. Most of these wells furnished gas to a large cement plant at Dewey, which was consuming about 5,000,000 cubic feet of gas daily. This field will soon be exhausted at the present rate of use.

One of the wells in the Osage district was blowing gas and oil at the rate of about 2,000,000 cubic feet a day and 40 barrels a day, respectively. This well produced, initially, about 2,000,000 cubic feet of gas daily from the Oswego limestone at a depth of 1,200 feet and between 4,000,000 and 5,000,000 cubic feet from another sand at a depth of 1,604 feet. This gas had been escaping for four months, and it was estimated that 420,000,000 cubic feet of gas had already been lost. It was impossible to take a sample of the gas from this well because of the oil which was carried with the gas to a near-by flow tank. A sample of gas (Lab. No. 3176), however, was taken from an adjoining well of about the same depth, 1,630 feet. A considerable amount of gas was formerly wasted. At present this well is connected with the lease lines and the gas is used for power and drilling purposes. The chemical composition and fuel value of this gas are shown in Table 2.

A second sample of gas (Lab. No. 3175) was taken from this locality. This well is only 1,150 feet deep. The gas is casing-head gas

and is utilized for power use. Its chemical composition and fuel value are shown in Table 2.

It was reported that other gas wells were wasting gas in this locality, but time did not permit taking more data.

HOGSHOOTER GAS FIELD.

The Hogshooter field lies along a narrow anticlinal ridge in Tps. 24 to 26, R. 14 E. The gas area is about 14 miles long and 3 miles wide and is named from a small stream that passes near the locality. This field was opened several years after the oil development of the Bartlesville pool. When the field was opened there was no market for the gas, and an immense amount was wasted. In 1910, however, a large company entered the field, and since then this area has been the chief source of supply to the Kansas and Missouri districts. In fact, it is the largest of the Mid-Continent gas fields. Several companies operate in this field, one of which furnishes gas to Joplin, Mo.

The Hogshooter field probably affords the most notable example of unwise exploitation in the Mid-Continent fields. The volume of gas available in this area led the large pipe lines to draw heavily from it. Some companies laid 18-inch lines into the field from Kansas. The field was rapidly depleted. Gas was taken from it without respect to the capacity of the wells or to the size, pressure, or facilities of other lines. The rapid depletion of the gas caused an inflow of salt water in parts of the field, and to-day the whole area is water bound.

At the present time the demand for gas has led the larger companies to establish three large compressor stations near the field, and the gas is drawn from the wells and pumped out of the State. If the operating companies had agreed upon reasonable pressures, connected their lines mutually, and agreed to take only 35 per cent of the daily capacity of the field, it would not be flooded at the present time and its life would be extended many years. In certain parts of the field the heavy drain caused the salt water to show in some wells after one month of flow. In such a case only 35 per cent of the daily capacity of the field should have been taken instead of 85 per cent, as has been reported.

The entrance of so many companies into the Hogshooter district reduced the rock pressure from 550 pounds in the winter of 1910 to 355 pounds in July, 1911, and to 80 pounds in December, 1912. In July of 1911, 158 gas wells averaged about 8,000,000 cubic feet of gas, with a total output of probably 1,264,000,000 cubic feet daily. During the cold weather of 1911 the rock pressure dropped at the rate of 1 pound a day. This loss was not made up during the following summer.

When the field was opened, the wells had no salt water in them. After the general rock pressure had declined below 400 pounds, salt water began to show in large quantities. Figures 5 to 8 show views in the Hogshooter district. Figures 6 and 7 show the field men relieving the wells and mains of water. Most of the wells are blown free of water each morning, this blowing sometimes taking as long as 20 minutes. Much gas is allowed to escape in this way. W. A. Johnson, of Bartlesville, stated that the waste in blowing off a gas well in this way is about 200,000 cubic feet for a 2-inch hole or 500,000 cubic feet for a 4-inch hole. The amount is dependent on the amount of water in the well. With three compressor stations operating in this field, at a low field pressure of 80 pounds, the life of the area must necessarily be very short. It seems to be the object of the operating companies to secure all the available gas as soon as possible.

FIGURE 5.—Blowing a gas well free of salt water.

Another man said that he observed wells in sec. 6, T. 24 N., R. 14 E., with original flows as large as 30,000,000 cubic feet daily. These same wells, as early as October, 1911, had been drowned until only a bubble came up now and then through the water, which stood within sight of the top of the well. The water had drowned out a rock pressure of 580 pounds. In the north end of the Hogshooter field some oil has shown in the wells as the pressure decreases.

FIGURE 6.—Blowing drip lines free of salt water.

The following figures from Haworth's report show the rate of decline of the Hogshooter field.

Decline of rock pressure of wells in the Hogshooter field.

	Original.	September, 1911.
Number of wells	40	40
Average rock pressure per well ..... pounds per square inch..	464	319
Average for 36 selected wells ..... do....		335

Decline in volume of wells in the Hogshooter area.

	Original.	September, 1911.
Number of wells	58	58
Total volume ..... cubic feet..	919,330,000	538,466,000
Average volume per well ..... do....	15,850,000	9,283,900
Average for 54 selected wells ..... do....		9,972,000

The Hogshooter field furnishes about 19,000,000 cubic feet of gas to three smelters in Bartlesville at a rate between 2 and 3 cents per 1,000 cubic feet. A gas line extends from the north end of the Hogshooter field to Bartlesville and supplies that town, in addition to smelters, with gas at a flat rate of $2.50 for cook stoves and heaters and 15 cents per light. The proportionate rate of consumption of gas in this locality is as follows:

Ratio of industrial to domestic consumption of gas in Hogshooter district.

Town.	Industrial.	Domestic.
Bartlesville	10	1
Dewey	6	1
Collinsville	12	1
Smaller towns	1	1
Tulsa	1	

Samples of gas were taken from a new $750,000 compressor station situated near the north end of the Hogshooter district (fig. 9). There are two general feed lines leading into this plant through which the gas is drawn. From here it is forced into the general feed lines that extend through Kansas.

A sample was drawn from the intake gage on the Collinsville line. The sample (Lab. No. 3177) is representative of the gas from the Collinsville pool in Tps. 21 and 22, R. 14 E. The chemical composition and fuel value of this gas are shown in Table 2.

Another sample (Lab. No. 3178) was taken from the gage on the Hogshooter line and is representative of that field. The chemical composition and fuel value of this gas are given in Table 2.

COLLINSVILLE FIELD.

The Collinsville gas area lies east and southeast of Collinsville in Tps. 21 and 22 N., R. 14 E. This field is not large, but its average original rock pressure was over 490 pounds, and the daily volume probably from 10,000,000 to 12,000,000 cubic feet. The drain, up to November, 1911, was light, as gas from other fields was supplied to Collinsville and Muskogee. Since 1911, a pipe-line company and several large plants in Collinsville have caused a rapid depletion of the area. The present rock pressure is about 130 pounds. There are 40 gas wells. Two smelters in Collinsville have used about 7,500,000 cubic feet of gas each a day during the past 14 months. The heaviest drain on the field took place in 1911. The field has been weakened to such an extent that pumps have been placed in the field to force gas to Muskogee, Wichita, and points in Kansas. The average depth at which gas is found is 1,210 feet, although small quantities of gas are found at depths of 360 and 890 feet.

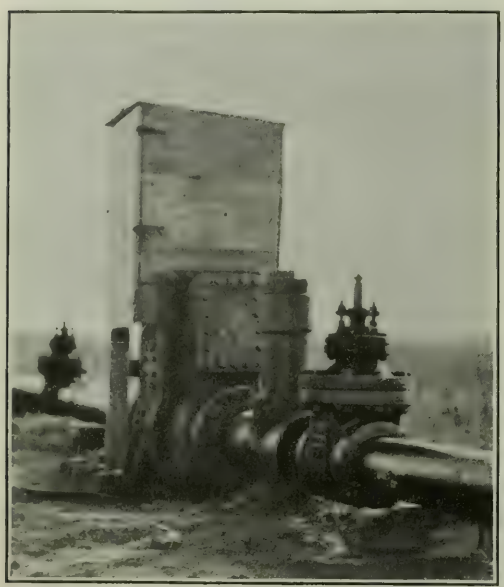


FIGURE 7.—A large field meter in the Hogshooter gas area.

Haworth's figures of the decline of the Collinsville field are as follows:

Decline of rock pressure of wells in the Collinsville field.

	Original.	September, 1911.
Number of wells	14	14
Average rock pressure per well ..... pounds per square inch..	530	456

Decline in volume of wells in the Collinsville field.

	Original.	September, 1911
Number of wells	10	10
Total volume ..... cubic feet..	188,014,000	152,900,000
Average volume per well ..... do....	18,801,400	15,290,000

OWASSA FIELD.

The Owassa field lies immediately east of Owassa in T. 21 N., R. 14 E. It was opened up in 1912. There were 14 active gas wells, and 4 new wells were being drilled. The total daily volume of this small field was about 64,000,000 cubic feet. A pipe-line company began operations in this field on October 8, 1912, and is drawing heavily on it. The average price obtained is 3 cents per 1,000 cubic feet. The original rock pressure of the field was nearly 400 pounds and the volume about 15,000,000 cubic feet per well. The depth of the strata overlying the producing sand is 850 feet. The wells show remarkable pressures for such a shallow depth. Another company is operating in this field, and up to December 7, 1912, had drawn off about 40,000,000 cubic feet of gas from 5 wells.

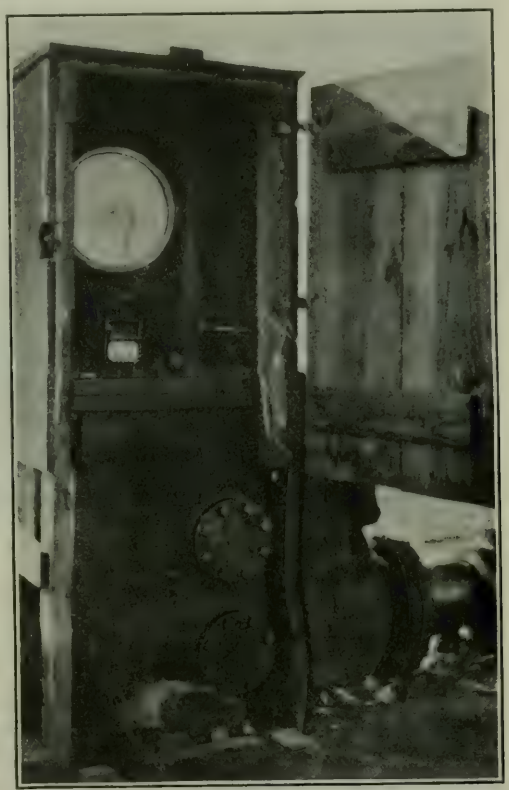


FIGURE 8.—Interior of meter box showing record sheet.

The gas from the shallow sands in this area was wasted while drilling for deeper producing sands was being done. This waste could have been avoided by use of proper methods of drilling.

NOWATA AND ADJOINING FIELDS.

The Nowata and adjoining fields are called in general the "Shallow" field, as the sands are found at depths of 250 to 750 feet. The production of gas has been light in these fields. Small amounts of casing-head gas have been produced.

ADAIR POOL.

The Adair pool lies in Tps. 25 and 26 N., Rs. 14 and 15 E., between the Hogshooter gas area and the Nowata oil fields. This area was recently discovered and is under development at the present time. Scarcely enough gas to operate the drills has been discovered to date,

and it has been found necessary to pipe gas several miles from the south for this purpose.

In some localities in Oklahoma many gas lines were seen to be leaking. They had obviously been laid quickly and carelessly. In the mains leading to the Adair pool three large leaks were observed, which were probably leaking from 100,000 to 150,000 cubic feet of gas a day. Similar conditions were observed in the Bald Hill and Schulter fields.

It is highly probable that new gas areas will be opened between the Adair and Nowata fields and in the Osage lands, as the geologic structure is favorable for the accumulation of gas. It is also probable that should gas be found in any quantity little of it will be

FIGURE 9.—A compressor plant.

piped out of Oklahoma, as the supply will not exceed the local demand.

BIRD CREEK AND FLAT ROCK FIELDS.

No data were taken of these fields, as little or no gas yield has been recorded from the areas. The Osage lands in the southeast corner of the reservation and immediately west of the Flat Rock pool have produced large quantities of gas, much of which has been wasted. No detailed data could be obtained except that the waste was very large. Robert Wood, of the United States Geological Survey, reported that gas was escaping from a large gas well in sec. 13, T. 22 N., R. 10 E., east of Hominy. The well had been flowing some time, and an attempt was being made to cap it about December 15, 1912.

TULSA FIELDS.

The Tulsa gas fields lie east and west of Tulsa, extending 2 or 3 miles in either direction. The gas wells east of Tulsa are capped and are furnishing gas to Tulsa. The wells are deep. The original rock pressures are as high as 500 pounds. The field is productive only in

places, however, and the sand is finer grained and less porous than that of the Collinsville area. The drain has been small on this area, as the larger pipe lines of the north have not extended their mains this far south. The surplus from this locality and other fields farther south will, in all probability, go into the lines which furnish gas to Oklahoma, Guthrie, Shawnee, and smaller towns.

Several wells east of Tulsa have produced volumes of probably 30,000,000 cubic feet a day. These wells are attached to pipe lines, and the gas is being utilized. The small gas area west of Tulsa has been the seat of much waste in the past. W. A. Johnson reports seeing a well in this area that gaged 69,000,000 cubic feet of gas daily, which was allowed to run open. It was exhausted nine months later. Such a well could not have wasted less than 5,000,000,000 cubic feet of gas.

The prevailing rate for gas in Tulsa is 16 cents per 1,000 cubic feet for domestic use and 3 to 7 cents per 1,000 cubic feet for industrial purposes. One company takes about 16,000,000 to 17,000,000 cubic feet of gas daily from the Tulsa and Glenn pool areas. The rate for this gas in the city of Oklahoma is 25 cents per 1,000 cubic feet for domestic use and from 10½ to 16 cents for manufacturing purposes. There are two large packing plants in this city that use 3,000,000 cubic feet a day.

Haworth presents some figures of the Tulsa areas that show the original pressures and volumes:

Decline in rock pressures of wells in the Tulsa fields.

	Original.	September, 1911.
Number of wells	17	17
Average rock pressure per well, pounds per square inch	527	94

Decline in volume of wells in the Tulsa field.

	Original.	September, 1911.
Number of wells	17	17
Total volume, cubic feet	74,218,000	20,053,000
Average volume per well, do	4,365,000	1,118,000

RED FORK AND SAPULPA FIELD.

A small gas area lies between Red Fork and Sapulpa that offers some interesting data as reported by Haworth:

Decline in rock pressure of wells in Red Fork and Sapulpa field.

	Original.	September, 1911.
Number of wells	7	7
Average rock pressure per well, pounds per square inch	650	0

Decline in volume of wells in Red Fork and Sapulpa field.

	Original.	September, 1911.
Number of wells	7	7
Total volume.....cubic feet..	78,000,000	0
Average volume per well.....do....	11,142,000	0

GLENN POOL.

The Glenn pool lies in Tps. 17 and 18 N., R. 12 E., to the east and southeast of Sapulpa. This is one of the greatest oil and gas pools that has ever been developed. It was discovered in 1906, and from that time the development was fast. A number of the wells produced large volumes of gas, both from above and in the oil sand. It is estimated that not more than 50,000,000 cubic feet of gas was consumed outside of field operations, and that billions, perhaps as high as 50,000,000,000, cubic feet of gas was wasted. Many wells with initial volumes of from 10,000,000 to 30,000,000 cubic feet flowed wide open for periods of one to eight weeks. The amount used was negligible in proportion to the amount wasted.

The present yield of gas from this area comes from the east side of the oil area and is found at a depth of about 1,400 feet. The strata dips west 35 to 40 feet per mile. Flows in the Glenn pool reported to have had original volumes of 30,000,000 to 70,000,000 cubic feet, exhausted in three or four months. The figures were, however, probably only rough approximations. Within the last two years a pipe line company has been taking the gas from the wells that are shut in and are still producing. Figures 10, 11, and 12 show views in the Glenn pool.

The present waste of gas in the Glenn pool is much less than it was and is confined chiefly to casing-head gas. Several lessees in the area have pumps attached to their wells and are drawing off the gas for gasoline extraction.

A sample of gas was taken from well No. 6 in sec. 3, T. 17 N., R. 12 E. The gas was flowing from an open pipe leading from the casing head (fig. 13). It was estimated that about 50,000 cubic feet of casing-head gas was escaping daily. The gas came from a depth of about 1,390 feet. The chemical composition and fuel value of this sample (Lab. No. 3215) are given in Table 2.

A sample of casing-head gas (Lab. No. 3216) was taken from well No. 5 in the SW. ¼ NE .¼ sec. 7, T. 17 N., R. 12 E. All the wells of this lease are connected to lease lines, and the gas is used for power purposes. The sample was taken to indicate its value for gasoline extraction. The chemical composition and fuel value are given in Table 2.

MUSKOGEE FIELD.

The Muskogee field lies west and south of Muskogee. But little gas is produced and that is used for field operations.

FIGURE 10.—A view in the Glenn pool.

FIGURE 11.—A well in the Glenn pool.

FIGURE 12.—Bird's-eye view of a pipe line pumping station.

POTEAU FIELD.

A small gas area of about eight wells lies near Poteau in Le Flore County. The average volume of the wells is about 2,000,000 cubic feet per day. The gas is used locally.

BLACKWELL FIELD.

The Blackwell field consists of a number of widely separated wells lying due north of Blackwell in Kay County. The wells in this field produce from 1,500,000 to 9,000,000 cubic feet of gas a day. The gas is all saved and is used locally. This field is well managed. The wells are spaced at considerable distance from each other, and the drain on the field is small in proportion to the capacity. Abundant oil seems to underlie the gas sand. This oil is being reserved until gas has been sufficiently exhausted to warrant deeper drilling.

FIGURE 13.—Waste of casing-head gas.

PONCA FIELD.

The Ponca oil and gas field lies south of the town of that name. The producing sands lie at depths of 500, 950, and 1,500 feet. The initial rock pressures of the wells vary from 375 to 425 pounds. The rock pressures of the older wells are now between 75 and 175 pounds. Several hundred million cubic feet of gas have been used locally at a rate of 25 cents per thousand cubic feet. Much of the Ponca gas is being piped at present to Arkansas City, Kans., where it is sold to a Kansas company.

The gas has been found with the oil in this area, and its saving has been made compulsory. It is stated that oil and gas can be separated by using double thicknesses of rubber on disk packers, if the packers are properly set. The Ponca operators have successfully used such packers.

The thoughtful operators will pack their gas back into the rock and conserve it for future use if a ready market is not at hand. It is literally bottled up in this fashion. One oil company, of Ponca City, has had complete success in this respect.

OSAGE FIELD.

The Osage field lies northeast and southeast of Osage Junction, Osage County. Probably the most willful waste of gas in the Mid-Continent fields has taken place in the Osage lands near this locality and in the adjoining Cleveland field. The operators maintain that the gas is in "combination" with the oil and must necessarily be wasted to obtain the oil. In reality, most of the gas from this area comes from a sand bed 12 feet above the oil zone. This could be saved by employing proper methods of drilling. Little gas really occurs with the oil. There is not a well in the locality but that will produce from 2,000,000 to 24,000,000 cubic feet of gas daily. It has been allowed to waste in the most extravagant manner. The worst waste took place around Osage.

CLEVELAND AREA.

The Cleveland pools extend from Cleveland southward for 6 or 7 miles. The region had two distinct developments. The old development was at a depth of 1,600 feet in what is known as the Cleveland sand, and the new development began in March, 1911, in the Bartlesville sand at a depth of 2,500 to 2,700 feet.

Most of the wells of this area produced immense volumes of gas, which in some cases flowed openly for a year. The gas yield was almost wholly wasted. One practical man shut his well in and furnished gas to the new drilling wells in this and near-by fields. He made a profit of $60,000 from the sale of gas and still has the well in use. In practically all of the Cleveland wells the gas is allowed to blow the oil into 1,600 and 2,400 barrel flow tanks. The casing heads are connected with 6-inch flow pipes, which allow the gas to flow at full volume. Had 2-inch tubing been used, the flow of gas would have been reduced, and the same amount of oil would have been obtained.

Very few of the Cleveland wells were gaged, but it is thought that each well produced from 3,000,000 to 30,000,000 cubic feet of gas daily. The initial yield of the oil well was 400 to 12,000 barrels a day. Much of the oil had been "cut" with gas and water and had accumulated in waste pits, mentioned previously under the head of oil residue. While driving through the Cleveland field several very rich wells were noticed flowing oil at a remarkable rate. Many of the wells were heard blowing oil and gas into large flow tanks. The gas could be seen shimmering from the top of the flues on the tanks, and often it was so rich in heavy vapors that it would sink to the ground. The valleys or gullies through some of the richer parts of the field were full of heavy gas, which seemed to hang like a fog over the ground. Numerous signs calling attention to the danger of smoking were nailed on fences and trees bordering the road. It was obvious that the gas from this area would have been very valuable had it been conserved and marketed.

Well No. 1, in the NE. ¼ sec. 1, T. 20 N., R. 7 E., known as the Lauderdale pool, was visited and a sample taken of the escaping gas. This well originally gaged about 12,000,000 cubic feet of gas a day from the Bartlesville sand. Gas was found at depths of 2,397 and 2,412 feet. The gas that was blowing at the time of the visit came from the full thickness of the sand, as the well had been drilled to a total depth of 2,442 feet. The waste of gas was about 1,500,000 cubic feet a day. The gas was blowing "cut" oil into a large waste pit. It is possible that the well had been drilled too deep and that water had been encountered below the oil, thus causing an emulsion of the two, which had to be separated by standing. The operators stated that some gas had been found above the lower end of the casing. This had blown or escaped into the open within a week's time. Some of the gas was saved by use of a "bradenhead," and was being utilized on the lease. It is safe to say that 100,000,000 cubic feet of gas had been lost. The chemical composition and fuel value of this sample (Lab. No. 3179) are given in Table 2.

A large amount of gas was observed escaping from the Martin No. 1 well in the NE. ¼ sec. 7, T. 20 N., R. 8 E. I was told that the volume of gas was between 12,000,000 and 15,000,000 cubic feet a day, and that it had been blowing for over 60 days through an extension pipe. The roar of the gas could be heard three-fourths of a mile. A large break was observed in a gas line on the same farm that was leaking perhaps 1,000,000 cubic feet daily.

A Cleveland operator said that the original rock pressure of the Lauderdale pool was 500 to 700 pounds. One or two wells were known to have registered a rock pressure of 270 pounds in 15 minutes, and a volume of 15,000,000 cubic feet. The gas came from the Oswego limestone overlying the regular producing sand. One Cleveland well flowed 24,000,000 cubic feet a day. The gas came from the Cleveland sand, at a depth of 1,600 feet. The Miller No. 1 well, in the Cleveland sand, had an initial rock pressure of 580 pounds. One well had a record pressure of 1,280 pounds and a flow of about 15,000,000 cubic feet a day. This was the well previously spoken of as having yielded a profit of $60,000 from the sale of gas. It is known as the McFall well and is located in the SE. corner NE. ¼ sec. 4, T. 20 N., R. 8 E. The total daily waste of gas in the field in January, 1913, was estimated at about 20,000,000 cubic feet.

It is said that in this area a well having an initial flow of 10,000,000 cubic feet of gas a day and a high rock pressure will flow for about five days without diminution of volume and then in two weeks' time the flow will diminish to 2,000,000 cubic feet a day.

A second sample of casing-head gas (Lab. No. 3180) from the Layton or "shallow" sand was taken from a well on the NE. ¼ sec. 2, T. 20 N., R. 8 E. The chemical composition and fuel value of this gas are given in Table 2.

CUSHING FIELD.

The latest field to be opened lies 12 miles east of Cushing, Okla.

The Cushing field was tapped in March, 1912, and since that time the development has spread remarkably fast. It is about 5½ miles long by 3 miles wide. At the time of the visit there were about 70 producing wells and about 75 rigs up that were either drilling or waiting for operations to begin. The upper productive sand of this field is known as the Layton sand. It lies at a depth of 1,400 to 1,600 feet. Although the yield of oil is light at the north end of the field, it becomes much better toward the south end. The Layton sand oil has a specific gravity as high as 0.791 (47° Baumé.) The Jones sand lies at a depth of 1,700 feet and the Cleveland sand at about 1,800 feet. The Wheeler sand is the deepest and most productive in the area. It lies at a depth of about 2,200 feet and produced a light green oil with a specific gravity of 40° to 42° Baumé. The daily production varies from 50 to 500 barrels per well.

FIGURE 14.—A large oil and gas well in the Cushing field.

Immense quantities of "wet" gas (gas mixed with oil vapors) are found at each well in the Cushing field. The amount varies from 4,000,000 to 20,000,000 cubic feet. About 15 wells in the area have blown an average of 4,000,000 to 5,000,000 cubic feet a day for several months. The gas of the area has not been measured except in the case of several "dry-gas" wells which lie along the eastern side of the field and are shut in for a future market. All the "wet" gas was being wasted, except in one case, where it was caught in a steel separator and utilized in an office building at the Fulkerson camp in the field. About 20 wells were observed flowing gas and oil through 6-inch tubing into flow tanks.

Figure 14 illustrates the method by which the larger wells are controlled and the oil and gas conveyed to the flow tanks. Figure 15 shows one of two large flow tanks in the area, from which immense quantities of gas were wasting. The roar of the gas from these tanks could be heard half a mile away. It was impossible to secure samples of gas from either the wells or the tanks because the wells were tightly closed and the flow pipes contained too much oil. A cotton

field was covered with oil for one-fourth of a mile in all directions. When the wells are completed, the gas blows the oil high into the air, whence it is carried by winds over the adjoining land.

Much gas was going to waste at the northern end of the field. Gas from a large pipe was burning openly with a flame 10 feet long. Near a boiler at the Polly Derrisaw No. 6 well a torch was burning in daylight with a flame 6 feet long by 2 feet wide. Gas was blowing through a 2-inch pipe at the rate of about 1,000,000 cubic feet a day. A sample of this flow was taken under difficult conditions. The gas came from the Layton sand at a depth of about 1,400 feet. The chemical composition and fuel value of this gas (Lab. No. 3213) are given in Table 2.

FIGURE 15.—A flow tank with 6-inch flow pipe.

The E. Wacoche No. 1 well, in sec. 29, T. 18 N., R. 7 E. (fig. 14), was observed flowing at the rate of about 2,000,000 cubic feet of foggy gas a day in an open flow tank.

The original and chief operators of this field were building a gasoline extraction plant and expected to place tight decks to their flow tanks and draw off the rich gas coming from their numerous wells. The gas contained about 4 gallons of gasoline to each 1,000 cubic feet. The capacity of the plant was about 7,000,000 cubic feet a day.

Several oil men have estimated that during the months of September and October, following the chief development in August, the waste of gas has amounted to 50,000,000 cubic feet a day. A conservative estimate placed the total waste of gas at 200,000,000 cubic feet since August. As very few wells have been shot because of the gas flow, the waste from the whole field may aggregate 1,500,000,000 cubic feet.

This field produces but little water except in the Layton sand in the northern end of the field.

One of the wells in this region had a daily production of 130 barrels.

The best gas well of the area was the Magnolia Mikey No. 1, in the NW. $\frac{1}{4}$ sec. 33, T. 18 N., R. 7 E. Gas was found at a

depth of 1,351 to 1,384 feet. The quantity increased at a depth of 1,411 feet, while the largest flow was found at a depth of 2,092 feet. The rock pressure of the gas inside of the casing was 725 pounds and outside of the casing 675 pounds and the original volume was estimated at 32,000,000 cubic feet a day. This well was shut in on July 30, 1912. Several "dry-gas" wells had been drilled along the same locality and all were capped, pending the introduction of new gas lines into Cushing and the construction of trunk lines.

A sample of "wet" gas was taken from the Fulkerson No. 1 well, in the NW. ¼ sec. 5, T. 17 N., R. 7 E. The waste of gas and vapors from this well was large. The chemical composition and fuel value of the sample (Lab. No. 3214) are shown in Table 2.

BALD HILL FIELD.

The Bald Hill area lies about 12 miles northeast of Okmulgee in T. 15 N., R. 14 E. The area is known as Bald Hill or Twin Hills. The waste in this territory has been considerable. Flow tanks are used in this field to catch the oil and the gas escapes. The daily waste of gas is about 8,000,000 cubic feet. The gas appears to be very rich and heavy as it leaves the tanks. Many leaky gas lines were observed over the field and considerable waste was noted.

The largest waste observed was from the Russel No. 1 well in sec. 30, T. 15 N., R. 14 E. This well had been drilled 10 days previous to my visit and had blown into the air for about 6 days. The estimated waste during this period was about 5,000,000 cubic feet a day. At that time the well had been partly closed, but a drill stem had been lost in the hole. The waste during the remaining four days was about 2,500,000 cubic feet, making a total waste of perhaps 40,000,000 cubic feet. The gas occurred with the oil at a depth of 1,680 feet. The gas was allowed to flow through a 2-inch pipe into the open. The gas was used in place of steam for driving the piston of the steam engine for this well.

A sample of gas (Lab. No. 3183) was drawn from the small lead lines around the well. The chemical composition and fuel value are shown in Table 2.

A second sample of gas was taken from the casing head of the Frank Lamb No. 2 well in sec. 22, T. 15 N., R. 14 E. The flow was perhaps 250,000 to 300,000 cubic feet a day. The chemical composition and fuel value of this gas (Lab. No. 3184) are shown in Table 2.

MORRIS FIELD.

The Morris field lies immediately southeast of Morris. Considerable gas has been found in the area. The wells are capped and the gas is used locally and in Morris and Okmulgee. This field was not visited.

The price of gas in Okmulgee was 25 cents per 1,000 cubic feet for domestic use and 3 cents for factories. There were one glass plant, two refineries, and several smaller concerns that altogether used about 1,500,000 cubic feet of gas a day. A new glass plant was being erected that was to use 6,000,000 cubic feet of gas a day. Gas lines were being laid from the Schulter field, mentioned below, to Okmulgee.

SCHULTER FIELD.

The Schulter field is a narrow pool about 4 miles long lying about 2 miles southeast of Schulter and 10 miles south of Okmulgee. In the northern part of this field the gas was not being wasted at the time of my visit, but the past waste had been enormous. During the early development, however, there was no ready market for the gas and, moreover, the operators were more interested in obtaining oil than in saving the gas found above it. The capacity of the wells was estimated at 500,000 to 50,000,000 cubic feet of gas a day, with an average of about 6,000,000 cubic feet a day. The gas flow, which went to waste, lasted from 2 to 14 days. The rock pressure had been reduced to 175 pounds. Most of the gas from the northern end of this field was used by a gasoline pumping station, which draws the oil and gas from the wells by vacuum pumps.

A plant for the manufacture of lampblack is situated in this field. There were 24 burning and gathering sheds. In each shed there were 1,520 tips, or 36,480 gas-burning tips in all. About 56 pounds of solids were obtained from 1,000 cubic feet of gas. From 1,500,000 to 2,000,000 feet of gas were burned daily.

The carbon company procured its gas from two wells in secs. 11 and 15, T. 12 N., R. 13 E. No. 1 well in section 11 was 1½ years old, 1,860 feet deep, and produced originally 3,000,000 cubic feet of "dry gas" at a rock pressure of 200 pounds. The rock pressure had decreased to about 150 pounds. Well No. 2 in section 15 originally produced 6,250,000 cubic feet of gas a day at a rock pressure of 175 pounds. On December 20, 1912, the rock pressure registered was 120 pounds in 10 minutes. This company was making preparations to buy gas from the lower end of the field in case the supply from its own two gas wells proved insufficient.

A sample of the gas (Lab. No. 3182) from the two wells of the carbon company was taken. Its chemical composition and fuel value are given in Table 2.

The lower end of the Schulter field is called the Bartlett pool. When visited, about 25 wells had been drilled since March, 1912, each of which had produced perhaps 15,000,000 to 30,000,000 cubic feet of gas daily. Most of this had been wasted. One of the chief operators

of this district said that the waste would approximate 15,000,000 cubic feet a day. For 300 days this makes a total waste of 4,500,000,000 cubic feet.

The Bruner Allotment No. 1 well, in the NW. ¼ SE. ¼ sec. 36, T. 12 N., R. 13 E., was visited. This well had blown gas for 296 days at an average rate of 6,000,000 cubic feet a day. The original flow of this well was given as 22,000,000 cubic feet a day. The total waste of gas from this well up to December 21, 1912, was estimated at 1,776,000,000 cubic feet. A sample of the gas (Lab. No. 3181) was taken for analysis. The chemical composition and fuel value are given in Table 2.

WHEELER FIELD.

The Wheeler field lies in the west central part of Carter County, in T. 3 S., R. 2 W. The development of this field began in 1904. The first wells of the area produced both oil and gas. Estimated daily flows of 6,000,000 cubic feet of gas have been recorded. The depth of the wells is about 850 feet. Since that time the development has spread and most of the wells have yielded large quantities of "wet" gas, which is separated by "bradenheads." The gas yield from the area has probably varied from 3,500,000 to 13,500,000 cubic feet a day. Most of the gas has been used in Ardmore.

THE FIELDS OF NORTHERN TEXAS.

PETROLIA FIELD.

The Petrolia field lies east of Wichita Falls, Tex. The gas in this field lies above the oil at a depth of 1,550 feet. Large quantities of gas have been produced and piped to near-by towns and cities. The gas is well conserved in this area. There was considerable early waste, particularly in the case of one well, about four years ago. Its reported original flow was 15,000,000 cubic feet. It was allowed to run open for 11 months, pending a lawsuit. At the end of that time the estimated flow was 10,000,000 cubic feet. The estimated loss from this well was about 4,000,000,000 cubic feet.

ELECTRA FIELD.

The Electra field lies west of Wichita Falls. This field has produced remarkable quantities of oil. There are about 10 producing sands, which are found at depths varying from 400 to 1,800 feet. It is reported that but little gas was found in this area.

RESULTS OF ANALYSES OF NATURAL GAS FROM OKLAHOMA WELLS.

The results of analyses of the samples of natural gas collected at some of the wells visited are given in the following table:

TABLE 2.—*Analyses of natural gas from Oklahoma.*

Locality.	Name of field or pool.	Production.		Depth to bottom of sand.	Estimated waste.		Laboratory No.	Constituents determined.				Claroline and alcohol absorption.	Gross heating value per cu. ft. at 0° C. and 760 mm.
		Oil or gas.	Number of sands.		Present.	Past.		CO_2.	CH_4.	C_2H_6.	N_2.		
				Feet.	*Cubic feet.*	*Cubic feet.*		*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per cent.*	*B. t. u.*
Sec. 30, T. 15 N., R. 14 E.	Bald Hill	Both	1	1,722	5,000,000 a day	40,000,000	3183	0.21	77.85	20.76	1.18	15.50	1,215
Do	do				500,000 a day		3184	.20	62.00	38.55	.00	25.00	1,377
Lot 44	Bartlesville (Osage)	Both		1,150			3175	.75	56.72	41.90	.63	26.30	1,383
Do	do	do		1,630			3176	.59	70.25	27.85	1.31	19.00	1,266
Sec. 4, T. 26 N., R. 13 E.	Bartlesville (Dewey)	do	1				3145	1.23	68.10	29.70	.27	21.00	1,378
Sec. 21, T. 27 N., R. 13 E.	do	do	1	1,330			3146	.72	76.50	22.45	.33	16.30	1,133
Gas piped from Tps. 21 and 22, R. 14 E.	Collinsville						3177	1.05	94.30		4.65	11.00	1,004
	Hogshooter						3178	1.00	94.20		4.8	11.00	1,003
NE. ¼ sec. 1, T. 20 N., R. 7 E.	Lauderdale	Both	1	2,442			3179	.61	67.56	23.52	8.31	17.60	1,147
NE. ¼ sec. 2, T. 20 N., R. 8 E.	Cleveland				Small amount escaping.		3180	.20	45.00	51.55	3.21	27.90	1,438
S.E. ¼ sec. 36, T. 12 N., R. 13 E.	Schulter			1,230		1,776,000,000	3181	.48	76.40	21.60	1.52	16.20	1,215
Sec. 11, T. 12 N., R. 13 E.	do	Gas	1	1,860			3182	.00	78.48	22.20	.00	17.70	1,249
	Cushing						3213	.20	66.60	24.45	8.75	15.90	1,164
Sec. 5, T. 17 N., R. 7 E.	do						3214	.00	61.20	30.25	8.55	17.50	1,214
Sec. 3, T. 17 N., R. 12 E.	Glenn						3215	.20	38.75	61.10	.00	28.50	1,551
Sec. 7, T. 17 N., R. 12 E.	do						3216	16.35	6.45	76.65	.55	20.70	1,495

[a] Analyses by G. A. Burrell.

COMMENT ON ANALYSES.

Regarding the characteristics of the gases represented by the samples analyzed, G. A. Burrell, chemist of the bureau, makes the following comment:

Of these samples only one (Lab. No. 3177), from the Hogshooter field, contains methane as the sole combustible gas. Olefin hydrocarbons, carbon monoxide or hydrogen were not present in any of the samples received. Some of the samples, especially laboratory Nos. 3184, 3175, 3180, 3215, and 3216 are rich in the higher paraffins and consequently are of relatively high heating value. One of the samples, laboratory No. 3216, contained much carbon dioxide, but has a high heating value because of the large proportion of the higher hydrocarbons, as indicated by the ethane content. An ordinary combustion analysis shows only the approximate proportions of methane and ethane and does not show the proportion of higher paraffins, if such are present. Methane and ethane undoubtedly predominate, and it is safe to assume that the higher the percentage of ethane the higher the proportion of propane, butane, etc., in the sample. Although the methane and ethane figures, when both are given, are only approximate, the determination of total paraffins (methane plus ethane) is quite close to the truth. The methane content given for sample laboratory No. 3177 is, of course, correct.

The constituents in three of the samples—Nos. 3182, 3184, and 3215—total more than 100 per cent, an error that probably is chiefly due to the probable maximum experimental error in determining the total content of paraffin hydrocarbons being 1.00 per cent. The carbon dioxide was determined with a probable error of 0.1 per cent. The second figures in the decimals have little or no significance.

All the samples have a high heating value and compare favorably with natural gas from the eastern fields. The natural gas used in Pittsburgh, Pa., which comes principally from West Virginia, has a heating value of 1,179 B. t. u. at 0° C. and 760 mm. pressure.

All but three of the samples are casing-head gases, were associated with oil, and their high heating value is due to contained vapors of the liquid constituents, pentane, hexane, etc., which have a much higher heating value than the gaseous paraffins, methane, ethane, propane, and butane, although these casing-head gases carry also a larger proportion of propane and butane than the so-called "dry" gases. Laboratory Nos. 3181 and 3182 correspond fairly well to much of the natural gas from the Appalachian fields that is used for heating and lighting towns.

The sample obtained from the Hogshooter field, as already mentioned, contains only methane as the combustible gas and is presumably fairly representative of the huge reservoir of gas in that field, although only a few miles distant are other reservoirs of gas, associated with oil, containing ethane and higher members of the paraffin series.

The suggestion is offered that the gas in the Hogshooter field may have had the same origin as other near-by gas, and in passing through porous strata under pressure may have lost, by condensation, the paraffins higher than methane. The presence of the carbon dioxide (1.05 per cent), which is even more easily liquified than ethane, may be accounted for by assuming that the carbon dioxide present was generated after the movement of gas had ceased—that is, in the Hogshooter field.

As regards the suitability of the gas for gasoline production, it can be stated that Nos. 3180, 3215, and 3216 show promise. However, their composition so closely approaches that of natural gas, which has not been profitable as a source of gasoline, that compression tests on a small scale would be necessary. The Glenn pool, from which samples 3215 and 3216 were obtained, yields much gas that can be used as a source of gasoline.

Attention is called to the high heating value of these casing-head gases. Coal gas has a heating value of only about 600 B. t. u. at 0° C. and 760 mm. pressure. The

utilization of casing-head gas presents difficulties that are not finally solved by gasoline production, for the heating value of the gas left after the condensation of gasoline is only a trifle less than that of the gas as it comes from the well.

THE VALUE OF NATURAL GAS IN OKLAHOMA.

The value of natural gas produced in Oklahoma is as follows: [a]

Value of natural gas produced in Oklahoma during the years 1902–1911.

Year.	Value.	Quantity.
		Cubic feet.
1902	$360	
1903	1,000	
1904	49,665	
1905	130,137	
1906	259,862	
1907	417,221	4,867,031,000
1908	860,159	11,924,574,000
1909	1,806,193	28,036,976,000
1910	3,490,704	50,429,646,000
1911	6,731,770	67,275,608,000
Total	13,747,071	

Number of productive wells, December 31, 1910	502
Number of productive wells drilled during 1911	364
Number of productive wells drilled January–November, 1912	413
Total productive gas wells	1,279

SUMMARY.

WASTE OF GAS.

The waste of gas in the Mid-Continent fields is treated for convenience under two heads, past waste and present waste. It will never be possible to estimate the amount of either loss with accuracy, because of the lack of information and the extent of development. The estimates that are given must necessarily be mere approximations.

PAST WASTE.

The chief waste of gas in Kansas took place in the early development of the Iola, Vilas, and Caney fields. No records were kept of the production. As the volumes were large, enormous quantities of gas must have been lost.

The chief waste of gas in the Oklahoma fields has taken place in the Cleveland-Osage area, in the Glenn pool, in the Bald Hill field, and in the Schulter field. The estimated annual waste in this State during the years 1910 and 1911 was about 100,000,000,000 cubic feet. Most of this took place in the Cleveland-Osage area, and in the Bald Hill and Schulter fields. The total waste previous to these years was probably about 150,000,000,000 cubic feet, of which one-third came from the Glenn pool and the remaining two-thirds, since 1902, from widely scat-

[a] Griswold, W. T., Mineral Resources U. S..1905, U. S. Geol. Survey, 1906, p. 802; Hill, B., Mineral Resources U. S., 1908, U. S. Geol. Survey, 1909, p. 338; Hill, B., Mineral Resources U. S., 1910, U. S. Geol. Survey, 1911, p. 302; Day, D. T., and Hill, B., Mineral Resources U. S., 1911, U. S. Geol. Survey, 1912, pp. 308, 309.

tered areas. The loss in 1912 was not so large as in previous years, but on account of the waste of "wet" gas in the Cushing, Schulter, and Bald Hill fields, and the waste in parts of the Osage lands, the total loss for the year is probably 25,000,000,000 cubic feet. The total loss in the past in the State of Oklahoma was about 365,000,000,000 cubic feet. It is not unlikely that the aggregate waste in Kansas was 50,000,000,000 cubic feet, if not more. The grand total of gas wasted in the Mid-Continent area, according to these estimates, would be 425,000,000,000 cubic feet. The writer is confident that this is a conservative estimate.

The total daily consumption of gas in the Mid-Continent area is about 100,000,000 cubic feet. At this rate enough gas has been wasted to have supplied the present demand for about 12 years. At the present rate of consumption in Oklahoma the gas that has been lost would have served this State for about 60 years. The intrinsic value of this lost gas, if it had been saved, would doubtless exceed the value of the oil that has been produced from these fields.

About 20,000 productive oil wells have been drilled in the Mid-Continent fields, from which there has been wasted to January 1, 1913, an average of about 300,000 cubic feet of casing-head gas per well. The total waste of gas from casing heads was about 6,000,000,000 cubic feet. The amount of gasoline that could have been extracted from the lost gas is variable, but undoubtedly it would have reached several millions of gallons.

PRESENT WASTE.

The present waste of gas in Oklahoma is taking place in the Cushing, Bald Hill, Schulter, Hamilton, and Cleveland pools, the south half of Osage Indian Reservation, and includes small amounts of casing-head gas that 75 per cent of the active oil wells of the region are producing. The approximate daily waste of the different areas is as follows:

Daily waste of gas in Oklahoma.

	Cubic feet.
Cleveland-Osage fields	15,000,000
Cushing field	15,000,000
Schulter field	15,000,000
Bald Hill field	8,000,000
Miscellaneous areas	10,000,000
Casing-head gas from active oil wells	7,000,000
Total	70,000,000

At this rate the total yearly waste of gas is 25,500,000,000 cubic feet. This amount will be reduced about 50 per cent during the coming year of 1914 unless new fields are opened beyond a ready market, because of the entrance of natural gas companies into the Cushing and Schulter fields. Both these areas will witness increased activity in gasoline recovery.

KINDS OF WASTE.

"COMBINATION" OR CASING-HEAD GAS.

Much "combination" gas, or gas rich in oil vapors, is wasted in the Mid-Continent fields, where immense quantities of gas and oil are associated. Such waste seems to be regarded by oil men as incidental and necessary in the opening of such fields as the newer ones of Oklahoma. As a rule, the operator is interested solely in producing oil from a new field, and the flow of gas is considered necessary for the production of oil. After the field has been either drained of oil or drowned by salt water, the yield of gas has so decreased that it is worthless. Therefore the operator is entirely responsible for this type of gas waste. Reasonable laws should be enacted and enforced for the preservation of as much of the gas as can be consistently saved, and ways and means devised for saving and utilizing such waste.

In most of the fields the gas is found above the oil and in the upper layers of the productive sand. In parts of the Cleveland and Cushing areas, the gas is found about 12 feet above the top of the oil sand and is often separated from it by a thin strata of shale. The gas should be sealed in the containing rock and conserved for future use.

Where the gas is actually mixed with the oil, methods should be devised for collecting and holding this gas until it can be utilized. In addition, an attempt should be made to interest operators in the manufacture of gasoline from gas. At this time, when motor fuels are in such demand, much can be done toward improving the present situation.

The latest methods of gasoline extraction should be put into general use. The saving of gas, vapor, and oil should be more critically studied throughout the oil fields and only those methods used that will give practically complete recovery of the entire yield of a well. Chemical analyses of all of the oils and natural gases from every section of the United States should be made, and the value of the gases for gasoline recovery ascertained and placed before the oil and gas men. It is surprising how little is known among the oil fraternity of the value of natural gas and the possibilities of recovering both oil and gas.

An efficient method of gasoline extraction that can be used on a small scale among the older oil fields needs to be devised. From many wells and leases in the older fields small quantities of casing-head gas are allowed to escape that could be utilized if the process could be adapted to smaller volumes.

By the use of vacuum pumps not only gas but lighter portions of the oil could be taken from the casing head and used for the production of gasoline.

Though it is understood that the gas and oil men are cooperating in many instances, to the profit of the oil operator, in utilizing the gas from oil wells, it should be borne in mind that there is a distinction between "dry" and "combination" gases. The first should be used directly as fuel and the second, if analysis warrants, should be used in the gasoline industry and should bring proportionably greater profit.

"DRY GAS."

In the development of most of the present oil fields, certain wells of the field have been found to yield gas alone. The gas from these wells is termed "dry" gas, and does not carry the vapors that accompany the gas associated with oil. In earlier days, unless a market was at hand, such wells were allowed to flow an unnecessary period before closing. Many of them were never closed. Within the last year or two, the demand for gas by the large pipe lines has done much to bring about the cooperation of oil and gas operators. The wells are closed as rapidly as possible and if the market is not at hand the wells are allowed to wait. Such an example is shown in the present development of the Cushing field, where several "dry" gas wells are closed, pending the building of pipe lines. Joint leases are now issued by which the gas operator takes the gas and the oil operator the oil.

In regard to the question of closing wells, several gas and oil operators have stated that it is possible to cap any gas well, regardless of its capacity; but, of course, this statement does not apply to wells improperly cased.

BRADENHEAD GAS.

Gas that is inclosed by a bradenhead is termed "bradenhead gas," for the lack of a better name. This term applies to all the gas which lies above the oil, and through which the drill must go to reach the lower and more profitable oil sands. Numerous instances were heard of where this gas was allowed to waste rather than devote time or a small expense to save it, which often was very large in amount. This can all be saved by the use of proper methods, and stringent measures should be taken against the man who willfully allows such waste.

ENGINE USE OF GAS.

The use of natural-gas pressure to drive steam engines, the gas escaping freely from the exhaust, is a willful waste that is not often practiced. A case of such abuse has been discussed under "The Bald Hill Field" (p. 41). If gas pressure is thus used, the exhaust should be connected to a low-pressure pipe line.

WASTE OF GAS BY TORCHES OR FLAMBEAUX.

The flambeaux law is quite generally broken in the Mid-Continent area. There are possibly 2,000 or 3,000 torches in use in these fields that burn day and night near the lease dwellings and power houses. Lights are indispensable in drilling at night and are used extensively about the rigs, but the open jets should be provided with tips, and should not be allowed to burn during the day. The field men consider it less trouble and cheaper in the end to let them burn all the time. As most of the gas consumed by flambeaux is casing-head gas, the oil men allege that shutting in this gas reduces the yield of oil; hence the continuous burning.

WASTE OF GAS BY FLAT RATE.

In several towns in the Oklahoma fields gas meters have not yet been installed. The gas is sold at a flat rate for each stove, heater, and light used. The use of gas under such conditions is not conducive to saving. As a rule, most of the heating and lighting devices burn day and night. The regulation of the temperature by opening and closing outside doors is not uncommon. It is possible that the increasing demand and decreasing supply of gas will soon compel the installation of gas meters in all localities.

CHEAP GAS FOR MANUFACTURING.

The rates for gas used by the industries, particularly in Oklahoma, are in many places ridiculously low. The price varies from 1½ to 16 cents per 1,000 cubic feet. Cases have been known in the oil towns of Oklahoma where 1½ cents per 1,000 feet has been the prevailing price. The average rate for factory use in or near the fields is 3 cents per 1,000 cubic feet. Where the gas is piped some distance, as from Tulsa to Oklahoma, the rate is from 10 to 16 cents per 1,000 cubic feet. The average for the State of Oklahoma is slightly over 5 cents per 1,000 cubic feet.

It is very seldom that the supply of gas is sufficient to equal the demand in domestic use, and this will prove to be the case, more and more, as the present Oklahoma fields decline. As natural gas is the cleanest of fuels and is particularly adapted to household use, it does not seem unreasonable to consider it as strictly a domestic fuel and not a commercial one. It should be limited to the use where it will do the most good.

The proportion of natural gas used in manufacturing to that used for domestic purposes is often as high as 10 to 1, and even in Kansas, where the supply is well-nigh exhausted, the proportion is more than 2 to 1. It often happens that competition in large gas fields reduces

the price to exceptionally low figures and as a result new plants and factories are built near the supply. An undue proportion of gas is thus forced into industrial use. The drain on the large fields is increased in proportion and the lives of the pools are greatly shortened. The price of gas in the Oklahoma fields, through industrial competition, is kept so low that there is little economic inducement to save gas. Therefore standardizing the price of gas will assure inducement for its complete conservation. All natural gas should be sold for not less than 25 cents per 1,000 cubic feet. Even at this figure the cost of gas fuel for all uses would be much less than the cost of coal or oil. It should not be sold for much less than the fuel it displaces. The fact that such an excellent domestic fuel is abundant and easy to win is not necessarily a reason why it should be put to industrial uses.

FREE GAS.

One of the worst features of the industrial use of gas is the inducement offered by "boom" towns or areas to manufacturers to erect plants near the supply, under the promise of free gas and an everlasting supply of it. Several factories have been induced to move from Kansas to Oklahoma on the strength of such offers. Instances are known where the gas lasted but a short time, and the operators were forced to resort to other fuel or abandon their plants. In such cases many companies fail and men are thrown out of employment. This was also true of Indiana during her intense gas excitement. Several towns were overbuilt because of gas inducements, and after the gas was wasted and the field abandoned they were partly deserted, and in the present day are known as "dead" towns.

EXPLOITATION.

The greedy exploitation of the extensive gas fields of Kansas and Oklahoma by the large pipe-line companies is one of the most deplorable features in the waste of natural gas. It is wrong for a large common carrier of gas to limit its gathering lines to certain areas, and then, in an effort to meet the excess demand, draw gas from the fields beyond their safe working value. Some of the greatest gas areas that have ever been developed have been depleted long before their normal life by drawing gas from them at a rate of 50 to 85 per cent of their daily capacity. When the field is overdrawn, the inevitable result is drowning by salt water. Not only are the immediate wells affected, but the whole territory is endangered and the more conservative gas operators are in danger of ruin from their reckless competitors. The lives of the wells are curtailed, often in a most startling way. It is reported that some wells of good yield are rendered useless within a month's time. The State law (1913) of Oklahoma limits the draft to 25

per cent of the natural flow. An attempt is being made to make this 15 per cent. Under the present condition the only remedy for such practice is absolute enforcement of a law providing for a draft not to exceed 25 or 35 per cent of the daily capacity of the field.

The wonderful Hogshooter gas field was ruined prior to 1911 by faulty methods of drilling and casing, by waste, and by drawing on the field too heavily. The more conservative companies had been drawing 40 per cent of the daily capacity, but when competition became sharper, all the companies began drawing on the supply as fast as it could be conveyed away.

It is evident that a gas trust would be one means of solving the problem, for in the development of a field the company would space the wells properly and would drain the field according to its safe working capacity. The pressures in the field would be equalized and this would lengthen its life.

Some companies have been known to enter a field and draw gas only from the wells near the trunk lines. The gas from these wells was drawn at 75 per cent of the daily capacity, without respect to the effect on other excellent gas wells that were in the same territory, but at some distance from the mains. In the Collinsville gas area a number of fine wells with rock pressures as high as 540 pounds were thus situated and without even being tapped the rock pressure dropped to 360 pounds. The closed wells lost much of their gas by excessive draining. Although the gas from the wells near the trunk line was being sold at a ridiculously low figure, the owners of wells farther from the mains were compelled to sell the gas or lose it entirely. In justice to the operators, feed lines to the different parts of a field should be maintained by the buyers.

THE SPACING OF GAS WELLS.

Excessive competition in the large gas fields has been caused by an irregular spacing of many of the gas wells and the result has been to hasten the depletion of the fields. The gas companies, above all things, should cooperate and place their wells so that the drain of a gas field would be uniform. Good results from proper spacing have been obtained in the Blackwell gas field.

IMPROPER PLUGGING OF WELLS.

In Oklahoma it is altogether likely that some abandoned wells have been improperly plugged, to the detriment of neighboring oil and gas accumulations. Plugs and the proper amount of filling material should be placed so that salt water can not leak into the oil sands from above or below.

THE USE OF VACUUM PUMPS.

Vacuum pumps should never be placed on the wells of a gas field until it is in its last stages of depletion. The unnecessary use of vacuum pumps in Oklahoma fields exhausted the wells with needless rapidity.

CONCLUSIONS.

The enforcement of drastic legislation to meet the problem of conserving natural gas has proved difficult. The gas and oil operators are opposed to, and perhaps fail to abide by, laws that work unreasonable hardships on their business. It seems therefore that a campaign of investigation and education is the best solution of the problem. This must be done in the fields and with personal cooperation and contact with the oil and gas men. These operators must be shown that it is to their profit to conserve oil and gas. The oil and gas men must eventually be relied on to put conservation into practice.

Two suggestions are offered for the prevention of needless wastes of gas. It should be made compulsory to use proper methods for conserving the gas found above the more important oil and gas bearing horizons. As has been pointed out, a large amount of the upper gas has been and is being wasted, and immense quantities of gas have been lost and fields have been prematurely invaded by water through failure to use the best methods in drilling and casing wells and through wasteful exploitation. No company has the right to endanger the life of a field by excessive drains of gas, and for the same reason no person should be permitted to use improper methods in sinking wells.

PUBLICATIONS ON PETROLEUM TECHNOLOGY.

Limited editions of the following publications are available for free distribution. Readers are requested to select publications of especial interest, as requests for all publications can not be granted. Requests for copies should be addressed to the Director, Bureau of Mines, Washington, D. C.

BULLETIN 19. Physical and chemical properties of the petroleum of the San Joaquin Valley, Cal., by I. C. Allen and W. A. Jacobs, with a chapter on analyses of natural gas from the southern California oil fields, by G. A. Burrell. 1911. 60 pp., 2 pls., 10 figs.

TECHNICAL PAPER 3. Specifications for the purchase of fuel oil for the Government, with directions for sampling oil and natural gas, by I. C. Allen. 1911. 13 pp.

TECHNICAL PAPER 10. Liquefied products from natural gas; their properties and uses, by I. C. Allen and G. A. Burrell. 1912. 23 pp.

TECHNICAL PAPER 25. Methods for the determination of water in petroleum and its products, by I. C. Allen and W. A. Jacobs. 1912. 13 pp., 2 figs.

TECHNICAL PAPER 26. Methods of determining the sulphur content of fuels, especially petroleum products, by I. C. Allen and I. W. Robertson. 1912. 13 pp., 1 fig.

TECHNICAL PAPER 32. The cementing process of excluding water from oil wells as practiced in California, by Ralph Arnold and V. R. Garfias. 1913. 12 pp., 1 fig.

TECHNICAL PAPER 36. The preparation of specifications for petroleum products, by I. C. Allen. 1913. 12 pp.

TECHNICAL PAPER 37. Heavy oil as fuel for internal-combustion engines, by I. C. Allen. 1913. 36 pp.

TECHNICAL PAPER 38. Wastes in the production and utilization of natural gas and means for their prevention, by Ralph Arnold and F. G. Clapp. 1913. 29 pp.

TECHNICAL PAPER 42. The prevention of waste of oil and gas from flowing wells in California, with a discussion of special methods used by J. A. Pollard, by Ralph Arnold and V. R. Garfias. 1913. 15 pp., 2 pls., 4 figs.

TECHNICAL PAPER 49. The flash point of oils; methods and apparatus for its determination, by I. C. Allen and A. S. Crossfield. 1913. 31 pp., 2 figs.

TECHNICAL PAPER 51. Possible causes of the decline of oil wells and suggested methods of prolonging yield, by L. G. Huntley. 1913. 32 pp., 9 figs.

TECHNICAL PAPER 57. A preliminary report on the utilization of petroleum and natural gas in Wyoming, by W. R. Calvert, with a discussion of the suitability of natural gas for making gasoline, by G. A. Burrell. 1913. 23 pp.

TECHNICAL PAPER 66. Mud-laden fluid applied to well drilling, by J. A. Pollard and A. G. Heggem. 1914. 21 pp., 12 figs.

TECHNICAL PAPER 68. Drilling wells in Oklahoma by the mud-laden fluid method, by A. G. Heggem and J. A. Pollard. 1914. 27 pp.

TECHNICAL PAPER 70. Methods of oil recovery in California, by Ralph Arnold and V. R. Garfias. 1914. 56 pp., 5 figs.

TECHNICAL PAPER 72. Problems of the petroleum industry; results of conferences at Pittsburgh, Pa., August 1 and September 10, 1912. 1914. 20 pp.

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